UK Natural Capital for Peatlands

Eurostat grant 05122.2017.003-2017.650

(Ecosystem extent, condition and service accounts and restoration cost accounts for Peatland)

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1. Executive summary

Peatlands occupy around 12% of the UK land area. This dramatic landscape provides over a quarter of the UK's drinking water and stores a significant amount of carbon making it an important habitat for providing both provisioning and regulating ecosystem services in the UK. Peatlands are also a major tourist destination and provide cultural history contributing significantly to the UK's cultural ecosystem service. They form some of the UKs most extensive wild spaces and are rich in rare and endangered wildlife boosting the UK's biodiversity.

Peatlands include both the highest and lowest value agricultural lands in the country. Agriculture on lowland peats, mainly in the east of England, include areas of high cropping value. However, this activity on peatlands has a negative impact on the peat from drainage and ploughing activities. It is estimated croplands on peat emit a total of 7,600 kt CO_2e yr^{-1} in the UK. Upland peat is used for livestock. When subsidies are excluded from farming income, livestock grazing has a negative contribution to ecosystem services for peatland.

Further developments are needed to produce repeatable condition mapping of UK peatlands. In addition, new data sources for the UK are needed to identify the currently poorly understood contribution timber, wind power, flood hazard regulation, water quality and recreation bestow to peatlands ecosystem services.

We estimated restoration cost accounts for the UK's peatlands. In the absence of a comprehensive plan to achieve this in the UK we initially used a blunt set of assumptions with the intent of highlighting the trade-offs involved and providing a conservative estimate of cost. The costs of restoring 100% of peatlands could be significant at between £8 and £22 billion but these are approximately 1/10th to 1/5th of the carbon emissions benefits that would be gained. More conservative estimates of the benefits of meeting the committee on climate change objective of having 55% of peatland in good status were of the order of £45-50-billion over the next 100 years.

2. Main Points

- Supply over a quarter of the UK’s drinking water, valued at £888 million in 2016.
- Climate regulation through carbon storage has a negative contribution to ecosystem services. Only 22% peatlands are in a near natural or rewetted condition, consequently CEH estimated peatlands emitting around 23,100 kt CO_2e yr^- GHG in total.
- Estimated time spent for recreation on peatlands in 2016 is 180 million hours valued at £274 million.
- Publicly funded research on Peatlands estimated to be £882,796 in 2018.
- The Net Benefits, in terms of climate change emissions alone, of restoring 55% of peatlands to near natural condition are estimated to have a present value of approximately £45-51 billion.

3. Collaboration

Department
for Environment
Food & Rural Affairs

The Office for National Statistics natural capital accounts are produced in partnership with the Department for Environment, Food and Rural Affairs (Defra). Further details about the natural capital accounting project are also available.

We would also like to thank colleagues at Centre for Ecology and Hydrology (CEH), Natural England (NE), Joint Nature Conservation Committee (JNCC), Scottish Natural Heritage (SNH) and Natural Resources Wales (NRW) for their invaluable comments and review of this work.

4. Background

This report was produced for Eurostat Grant number 05122.2017.003-2017.650 by the Office for National Statistics as part of the ‘Ecosystem extent, condition and service accounts and restoration cost accounts for Mountains, Moorland and Heath and Peatland’ project.

This report describes the state of the UK’s peatlands, using the latest information available on the extent, condition and land use types. It follows on from the JNCC Report No. 445

‘Towards an assessment of the state of UK Peatlands’ and Defra report for Project NR0165 ‘Developing Peatland Carbon Metrics and Financial Modelling to Inform the Pilot Phase UK Peatland Code’. It also includes the natural capital assets provided by the peatlands and critically considers the sources of information. Information has been drawn from a wide range of sources, with this report attempting to understand the different descriptions and analysis to provide a reasoned picture of the state of the UK peatlands.

5. Introduction to Natural Capital

Nature provides the basic goods and services that make human life possible: the food we eat, the water we drink and the plant materials we use for fuel, building materials and medicine. The natural world also provides less visible services such as climate regulation, natural flood defences, removal of air pollutants by vegetation, and the pollination of crops by insects. Then there is the inspiration people take from wildlife and the natural environment.

This report includes ecosystem services and the values of those services. This helps us to think logically about what aspects of the natural world we are measuring and how they impact on people.

Natural capital assets are the things that persist long-term such as a peat bog or food and wool from livestock grazing. From those assets people receive a flow of services such as recreational hikes on the peatlands and livestock grazing on upland areas. Finally, we can value the benefit to society of those services by estimating what the hikers spent to enable them to walk over the peatlands or the profit to the farmers of bringing the livestock into the market. Applying this logic consistently across assets and services enables us to start building accounts of the value provided by nature.

The benefits we receive from nature are predominantly hidden, partial or missing from the nation’s balance sheet. However, by recognising nature as a form of capital and developing accounts of natural capital’s contribution to the economy and our well-being, decision-makers can better include the environment in future policy planning.

The development of natural capital accounts has been flagged by the Natural Capital Committee and the UK National Ecosystem Assessment as a fundamental activity that is necessary if natural capital is to be mainstreamed in decision-making.

There has also been strong international momentum to develop natural capital accounts. The UN System of Environmental-Economic Accounting (SEEA) is the main source of technical guidance and sharing of experiences, the principles of which these accounts are built upon.

In 2011, the Department for Environment, Food and Rural Affairs (Defra) committed to working with the Office for National Statistics (ONS) to measure the value of UK natural capital (see Natural Environment White Paper, June 2011). Since then, the ONS has collaborated with Defra to develop innovative methods to measure this strand of economic statistics, with an objective of including UK natural capital estimates in the UK Environmental Accounts by 2020.

Natural capital accounts include stock accounts of specific habitats and flow accounts of services. Both physical (non-monetary) accounts and monetary valuations are presented as a time series to monitor change over time. Monetary valuations of natural capital begin to reveal the value of benefits provided by nature. Valuations were developed under the principle of comparability with the 1997 to 2015 UK Ecosystem Service Accounts and consistency between individual ecosystem services.

It is recognised that the UK accounts remain experimental and future UK publications will be subject to methodological improvements over time. Ecosystem service valuations offer comparative analysis across services whereas physical flows provide information about the changes over time independent of price changes. The services are presented by type, which include provisioning, regulatory and cultural. Types of service are defined at the beginning of each section.

All estimates are experimental and are subject to adjustment and improvement as the natural capital accounts are developed. A number of ecosystem services are not being measured in this report, so the monetary accounts should therefore be interpreted as a partial or minimum value of Peatlands natural capital.

6. Introduction to peat

This section of the report introduces what peat is, the uses of peat and broad issues on data collection.

6.1 What are peatlands?

Peatlands are wetland landscapes that are a unique ecosystem formed of partially decomposed plant and animal remains. The wet and acidic conditions slow decomposition enabling organic matter to gradually accumulate over centuries and millennia to form deep peat deposits. Peat in a good condition contains around 90% water, with its key component *Sphagnum* having an ability to store 20 times its weight in water. Sphagnum's ability to store water in dry conditions both protects the peatland through droughts and enables it to spread the same conditions into drier adjacent land.

These are habitats with a unique biodiversity and are recognised as of national and international significance (JNCC, 2011). These areas provide an archive of change over time. The peatland archive forms a multi-proxy record of its formation as it contains plant macro- and microfossils, archeological remains, volcanic ash, animal remains, charcoal and other natural or anthropogenic materials. A chronology is developed from oldest to youngest, with the deepest deposit being the oldest and the younger ones closer to the surface (Greiser & Joosten, 2018).

Peatlands provide significant water resources to larger parts of the UK and are also areas with a significant proportion of the UK's soil carbon store (Billet et al., 2010). In the UK it is estimated there is over three billion tonnes of carbon stored in the peatlands, equivalent to all carbon stored in the forests in the UK, Germany and France together (Moors for the Future, 2019). The amount of carbon stored in Scottish peatland is equivalent to 140 years' worth of Scotland's greenhouse gas emissions (SNH, 2017b).

Peatlands in the UK can be referred to as either a soil type or habitats such as fens and bogs. In the UK there are three broad peatland habitats.

Blanket bog – these are peatlands which receive all their water from precipitation and typically form across a hilly landscape (SNH, 2014). These are globally rare, although in the UK this is the largest peatland habitat. As a consequence of only being fed by precipitation they are nutrient poor and acidic (IUCN, 2018).

Raised bog – form in the lowlands on wet floodplains or in basins, often on the surface of existing fen peats (Bruneau & Johnson, 2014). They form localised domes of peat. They are also nutrient poor and acidic due to being fed by precipitation and they have similar plant species to blanket bog.

Fens - these receive water from precipitation and ground water that has been in contact with the underlying geology. Consequently, they exhibit a wide range of types, including base-poor fens resembling bog-type vegetation of cotton grass, heather and *Sphagnum* mosses to fens rich with sedges, reeds and brown mosses (IUCN, 2018).

A peatland landscape can display a complex combination of blanket bog, raised bog and fens. Upland blanket bogs can be interspersed with nutrient poor fens, whereas raised bogs can grade into fringing 'lagg' fens (SNH, 2014).

An internationally accepted definition is the Ramsar Convention 1971 proposed definition "ecosystems with a peat deposit that may currently support a vegetation that is peat-forming, may not, or may lack vegetation entirely. Peat is dead and partially decomposed plant remains that have accumulated in situ under waterlogged conditions" (Smyth et al., 2015).

6.2 Peat vegetation and land use

The different land management uses of peatlands can have a significant impact on the condition. How a peatland functions is influenced by its vegetation. Changing the vegetation can change the hydrology and the geochemical conditions. Peatland in a poor condition can release carbon rather than storing it. This changes the quality of the water in the rivers and increases the amount of greenhouse gases emitted into the atmosphere.

There is currently no available data in the UK for the same year on the different habitats peatlands can be found. Most of the data available referrers to fens, marshes, swamps and bogs. Peat also exists below forests, farmland and grasslands. The report by Evans et al. (2017) does include the latest estimations on peatland condition by categories, a summary table below (Table 6.1).

Table 6.1 Summary of habitats for UK peatlands (Evans et al., 2017)

Habitat	ha	%
Cropland	194,125	7
Forest	439,292	15
Grassland	234,761	8
Bog	1922016	65
Fen	27545	1
Extracted	144887	5
Total UK	2,962,626	100

6.3 Protection

The UK has a variety of habitats that are protected by having a specific designation which have legal protection. Sites can be important for their plants, animals, geology or landform features for national or international importance.

A large variety of specialised animals and plants are adapted to the acidic, waterlogged and nutrient-poor conditions of peatlands. These species are increasingly threatened or rare and there have been noticeable reductions in distributions and populations due to land management changes and other external drivers. As a result, peatlands are recognised as being a conservation priority in the UK. An example being the bird assemblage which has led to large areas being designated Special Protection Areas (Smyth et al., 2015). Blanket bog is an important feeding and nesting habitat for birds, especially upland species like dunlin and the golden plover. Bog habitats also have a diverse range of dragonfly assemblages, more than any other British habitat.

Looking at the condition of these protected sites located on peatlands gives an indication of the general condition of the peatland. These sites have a statutory obligation to report their condition as favourable, recovering or unfavourable.

6.4 Physical Condition

The IUCN estimates 80% of the UKs peatlands are in a damaged and deteriorating condition having been modified as a result of present and past land management activities, including extraction for horticulture and draining for agricultural improvement (IUCN, 2018). Evans et al. (2017) estimates around 640,000 ha remains in a near-natural condition (approx 22% of UK peatlands).

Quick et al. (2013) identified that it is important to know the condition of peatlands as it is a major store of carbon. The deep peat can store carbon for hundreds or thousands of years. Peatlands in a good condition are better at storing and long-term sequestering of carbon. Whereas, degraded peatlands will emit greenhouse gases. See table 6.2 for the impacts of different peat conditions.

Table 6.2 Impact of peat condition on Greenhouse Gas emissions (Quick et al., 2013)

Peatland condition	Type of ecosystem service	Quality of ecosystem service	Flow of ecosystem service	Effect on climate
Healthy peatland	Carbon sequestration and carbon storage	Very good	Improving	Positive
Grazed peatland	Carbon storage	Adequate	Steady or deteriorating	Variable
Burnt peatland	Carbon storage	Adequate	Steady or deteriorating	Variable
Degraded peatland	Carbon storage	Poor	Deteriorating	Negative
Eroding peatland	Carbon storage	Very poor	Deteriorating	Negative

The condition of an ecosystem asset, in terms of its characteristics, reflects its overall quality. The relationship between the extent and condition of ecosystem assets is likely to be non-linear and variable over time (UN SEEA, 2014; para 2.34). The condition of an ecosystem asset plays a large part in determining the quantity and quality of services the asset provides and its capacity to provide those services into the future. If the peatland is in a degraded state, over time the ecosystem services provided will be less than if the peatland was in good condition and being used sustainably.

6.5 Data

Historically there have been different approaches to defining peat, including being based on geology, soils, vegetation or hydrological conditions. The different approaches in collecting data and recording peat deposits has implications when trying to assess the extent and condition of UK peatlands.

Data on peat is collected at country level. This makes assessing compatible data at the UK level problematic, as the 4 countries do not even agree on the definition of what is peat when it comes to mapping the extent. The definition for England and Wales is peat needs to have a thickness of 40cm or greater and 50 cm in Scotland and Northern Ireland of peat material. Furthermore, there is a gap in knowledge on the depth of these extensive deposits, making it a challenge to estimate the total volume of the peat deposits in the UK and the amount of carbon locked away in it. There are many data issues relating to peat and they will be discussed further in section 7.6.

7. Extent and condition

This section of the report investigates the extent and the condition of the peatlands. In addition, the uses of peat and the extent of peatlands protected by statutory designations.

7.1 Peatland extent

The extent of the peatland in the UK is not precisely known as it has been measured differently under different definitions in the four regions of the UK. Key data sources have been the Land Cover Map (LCM) 2007, the Land Cover of Scotland 1988 (LCS88), the Countryside Survey (CS), British Geological Survey (BGS), national soil surveys and soils, biodiversity and environment monitoring schemes, which are often point-based. These sources have different definitions of peat and different levels of accuracy (JNCC, 2011). The LCM2007 is not accurate enough to identify the extent of peatland in the UK. It needs to be overlaid with data from ongoing country peatland mapping work (Smyth et al., 2015).

The JNCC (2011) report ‘Towards an assessment of the state of UK Peatlands’ was the first time a range of different sources was used to identify peatland extent in the UK. The following sources for identifying extent in UK were used:

- England - A map showing the extent of England’s peatlands was produced by Natural England based on the National Soils Map, British Geological Survey superficial geology data, and BAP Priority Habitat mapping for Blanket Bog.
- Wales - Areas of different peatland types in Wales derived from soils, geological and habitat maps.
- Scotland - The location and extent of Scottish peatlands came from the Soil Maps of Scotland dataset.
- Northern Ireland - The sources of information on peatland extent, management and condition have been largely derived from the Soils Map of Northern Ireland, Northern Ireland Peatland Survey, Landcover Map 2000, the Northern Ireland Countryside Survey 2007 and detailed surveys and monitoring relating to designated sites.

The JNCC (2011) investigated the extent of shallow peaty and deep peat soils across the UK based on soil mapping and Biodiversity Action Plans (BAP) (Table 7.1). As there are different methodologies for data collection in the four countries it is not possible to draw a direct comparison. Although it does suggest that bogs and fens are more extensive in England as a proportion of the area with peat soils, while Scotland hold most of the UK’s peat soils.

Table 7.1 Summary of organic-rich soils extent in ha (JNCC, 2011)

	Soil map data		UK BAP data	
	Shallow peaty or Organo-mineral	Deep peaty or organic soil	Bogs	Fens
England	738,618	679,926	272,719	8,000
Wales	359,200	70,600	71,830	6,200
Northern Ireland	141,700	206,400	160,902	3,000
Scotland	3,461,200	2,326,900	1,772,000	8,585
Total	4,700,718	3,283,826	2,277,451	25,785

The JNCC (2011) concluded from their report that despite a broad agreement on what is a peatland that there is little convergence on the methods used to quantify peatlands around the UK. There is a significant difference in information coverage and intensity of data recording across the UK. More consistent information is needed to gain greater understanding on the function of peatlands.

It is a significant challenge to compile a consistent UK base map of peatlands. Several national soils maps exist, however, they all have limitations regarding resolution. The latest estimations on peatland extent from the Implementation of an Emissions Inventory for UK Peatlands project calculated an estimated total area in the UK of around 3.0 million hectares (12.2% of total UK land area), see Table 7.2 for area by country. Of this around 640,000 ha (22%) is estimated to be in a near-natural condition. To calculate the total estimated peatland area the project used national peat depth definitions of 40 cm in England and Wales and 50 cm in Scotland and Northern Ireland. They did not include soils with a peaty organic horizon over mineral soil even though they are extensive in the UK as they do not meet national definitions of peat. When this new data is compared to the JNCC calculations of 2011 the estimated areas of peat have changed significantly, except for England. The latest mapping has been more effective at identifying the small peat units. However, there remains some uncertainties over the location and extent of all deep peat across the UK (Evans et al., 2017).

Table 7.2 Total estimates peat areas for UK administration (Evans et al., 2017)

Country/administration	Peat area (ha)	Source data	Reference
Scotland	1,947,750	James Hutton Institute, British Geological Survey	Evans et al. (2017)
England	Deep: 495,828 Wasted: 186,372	National Soil Research Institute, British Geological Survey	Natural England (2010)
Wales	90,050	British Geological Survey, Natural Resources Wales	Evans et al. (2014)
Northern Ireland	242,622	Deep peat from British Geological Survey, Agri-Food and Biosciences Institute, Peat Survey of Northern Ireland	Cruikshank & Tomlinson (1990); Evans et al. (2017)
Total	2,962,622		

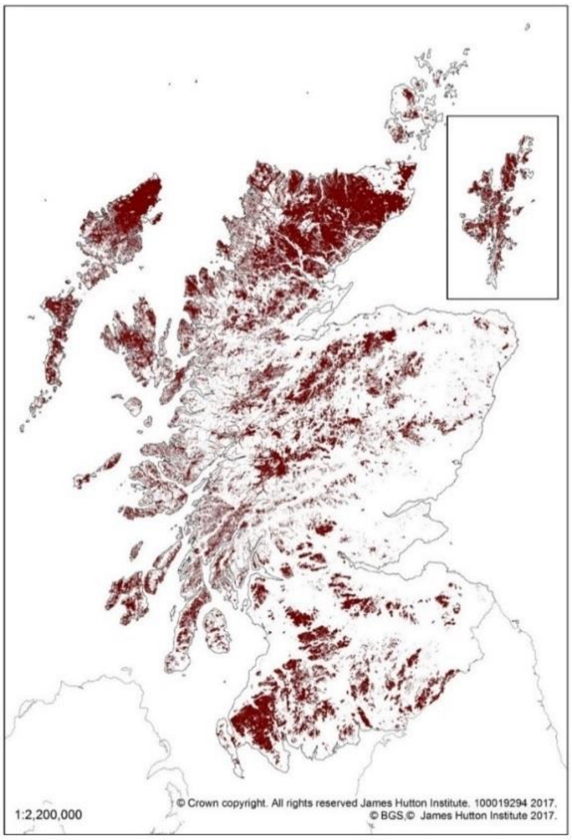


Figure 7.1 Scotland peat base map (Evans et al., 2017)

The Scotland map (Figure 7.1) was compiled from the 1:250,000 Soils map of Scotland (James Hutton Institute), British Geological Survey 1:50,000 Geological map of Great Britain, National Soils inventory data and consultations with soils experts. This map being the first ‘unified’ map of peat presence in Scotland with a total peat area of 1,947,750 ha (Evans et al., 2017).

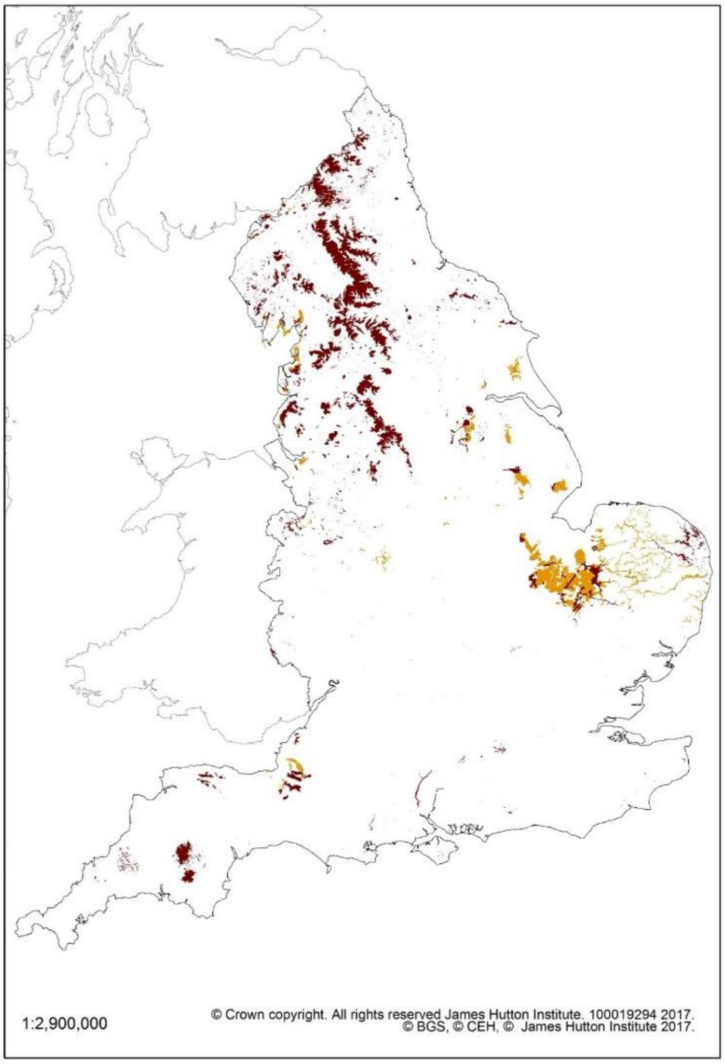


Figure 7.2 England peat base map (deep peats shown in brown, wasted peats in orange) (Evans et al., 2017)

The England map (Figure 7.2) used a unified base map that already existed from British Geological Survey and National Soil Resources Institute data. Total area mapped for England was 495,858 ha on deep peat and 186,372 ha wasted peat (Evans et al., 2017).

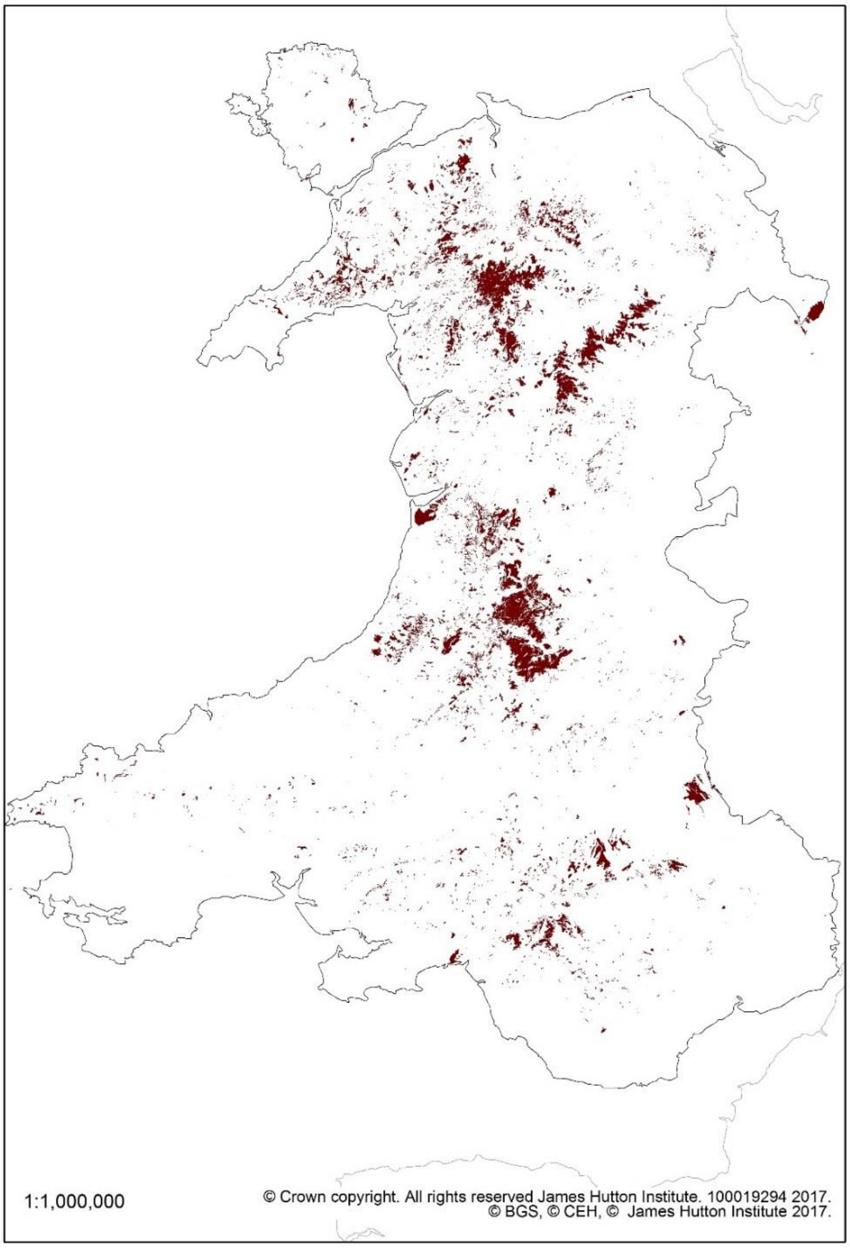


Figure 7.3 Wales peat base map (Evans et al., 2017)

The Wales peat base map (Figure 7.3) was developed by Evans et al. (2015) in a project for the Welsh Government. It is based on British Geological Survey 1:50,000 superficial geology data set and survey data from Natural Resources Wales. Total peat area mapped is 90,050 ha (Evans et al., 2017).

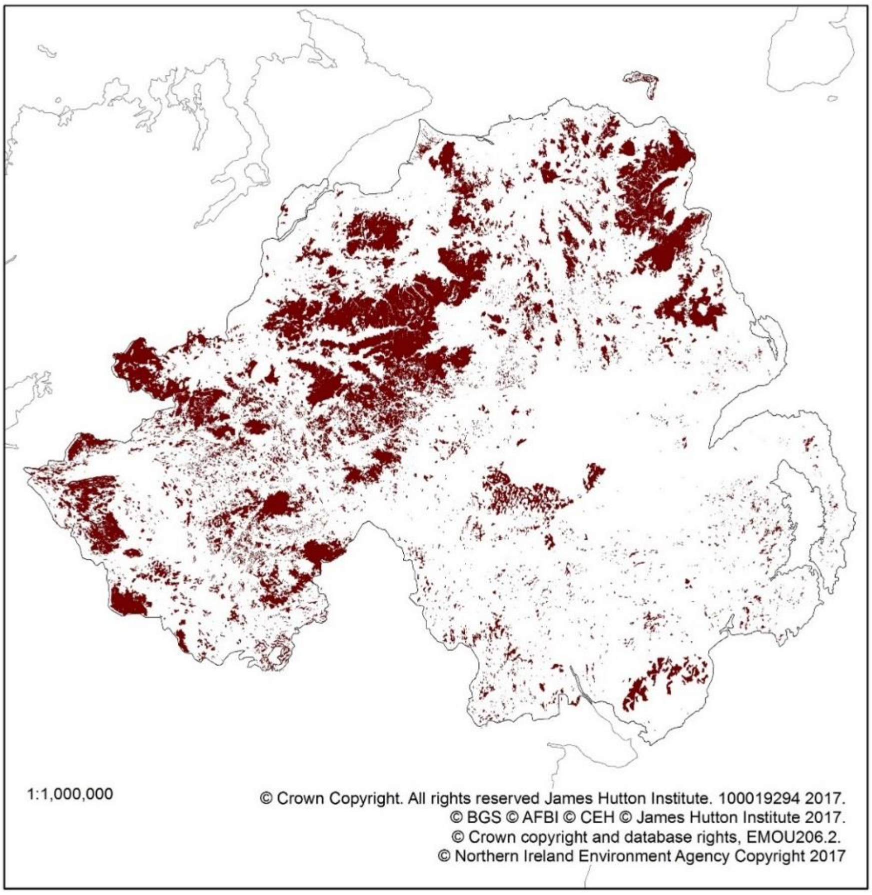


Figure 7.4 Northern Ireland peat base map (Evans et al., 2017)

The Northern Ireland map (Figure 7.4) is based on the British Geological Survey 1:10,000 superficial geology dataset, the Agri-Food and Biosciences Institute soil survey 1:25,000, the 1988 Northern Ireland Peat Survey and inspection of aerial photographs and site visits. The mapped area of peat in Northern Ireland is 242,622 ha (Evans et al., 2017).

7.2 Peatland land management and uses

The land management on the peatland influences the vegetation. Although the UK peatland area is around 12% of the UK land area, only around a quarter of this is in a near-natural or rewetted state. The rest is degraded due to afforestation, extraction for horticulture, drained to grow crops, cattle grazing and moor burning.

Evidence suggests that former peat extraction areas which are abandoned but not yet restored do not return to functioning peatlands unless there is restoration intervention (Evans et al., 2017). Bruneau & Johnson (2014) identified in Scotland that bare peat is a dominant land cover during peat extraction and is normally replaced by other land cover after cessation of the peat extraction.

In the UK commercial peat extraction is mainly for horticulture or energy. This process removes the peat from the ground with its stored carbon. The current rates of extraction substantially exceed the original deposition rate. Peat accumulates at less than 2 mm per annum compared to modern extraction rates 100x that depth. As the gardening sector is expanding there is still a demand for peat as a soil conditioner (IUCN, 2014). Current peat extraction accounts for around 1 $MtCO_2e$ of emissions each year (Committee Climate Change, 2018).

In Northern Ireland extraction for peat is subject to approval by the Planning Service if it is for commercial purposes. The declared land owner is entitled to extract peat for domestic use, subject to statutory provisions. The introduction of mechanized peat extraction in the 1980s has led to an estimated 6% of the blanket bog being affected (NIEA, 2011). Cutting peat for fuel has occurred on 77.5% of raised bogs, mainly for domestic purposes (O'Hare & Woodrow, 2004). The UK Government has stated in the 25-year Environment plan (2018) an action to restore our vulnerable peatlands and ending peat use in horticultural products by 2030.

There are a few sites where trees naturally occur on ombrotrophic (water only from precipitation) bog peat, as consequence in the UK the majority of bogs are open. Between the 1950s and the 1980s approximately 9 % (190,000 ha) of the UK's deep peats were drained for forestry plantations because of new planting techniques and tax incentives. This has now been halted due to removal of tax incentives and new policy to stop planting on peat. The impact on the peat from drainage is to lower the water table. Undrained peat bogs have a high-water table, usually within 10–20 cm of the surface of the peat. This is substantially lowered with afforestation. In addition, the chemical and physical properties of the peat change which affects the hydrology (Sloan et al., 2018).

NRW has estimated that there are 18,092 ha of woodlands established on deep peats in Wales (soils in which the organic content of the surface horizon is > 80% and the peat depth is >40 cm). This includes 11,232 ha under coniferous tree cover (Vanguelova et al., 2012). The afforested peatland cover in England is estimated by the JNCC to be 33,156 ha. In England it is mostly coniferous plantation forestry. This is land that was marginal for agriculture, often deep peat in the uplands. The land was deep ploughed and drained, resulting in the loss of *Sphagnum* and peat forming vegetation (CCC, 2013). The Northern Ireland Peatland Survey and Landcover Map 2000 reveals scattered conifer plantations occurring widely on peat. The most extensively forested peat in the UK is in Scotland. Recent estimates suggest 17% of deep peats in Scotland are forested, approx. 150,000 ha (Payne & Jessop, 2018). Extensive areas of uplands peatlands in Scotland have been deep ploughed and planted with non-native coniferous trees (Bruneau & Johnson, 2014). Scotland has some bog woodland, which is one of their rarest habitats. Scots pine being the main tree species with the underlying bog being similar to an open bog (SNH, 2015). It is estimated around 15% of UK peatlands is currently tree covered, with the majority being secondary from direct planting or invasion of the trees onto degraded peatland (Payne & Jessop, 2018).

One of the most common use for upland peatlands is livestock grazing, sheep and cattle. On some sites, livestock grazing can also be used to control scrub and tree regeneration. The most active peatlands can only sustain light seasonal grazing as the vegetation is of low productivity. If there is too much grazing the peat forming vegetation becomes modified (Bruneau & Johnson, 2014). Research by Rawes & Hobbs (1979) concluded a major influence on the botanical composition of blanket bogs was sheep grazing. In England the uplands areas have around 3 million sheep (45% of the national stock). Approximately 300 km^2 of the deep peat has been impacted from overgrazing, despite a decline since the 1950s in stocking levels. In England 750 km^2 has been drained for agricultural use in the 19th century and the 1970s. Since 2007, and the payment of £27 million to livestock farmers through the Rural Development Programme for England, there has been a reduction in grazing intensity by over 40% (3,000 km^2) in the uplands (CCC, 2013).

Peatlands are important as agricultural land where their potential depends on the critical management of water regimes, including intensive drainage and protection from flooding (Graves & Morris, 2013). In England around 240,000 ha of lowland peat is used for farming and food production. In order to achieve this the land has been drained, especially in eastern England for high value cropping. If this peatland was restored and taken out of food production, it could affect the national production of food at a time when there is high global demand. Farming on the deep peats in Humberhead and the Fens is profitable with net margins around £360-£420/ha/year and £1000-£1300/ha/year for vegetables and salad production is close to 60% of the cropped area. Grassland areas of Lyth Valley and Somerset have net margins around £160-£220/ha/year and maybe higher if more dairy. Continued use of farming on peatlands does lead to degradation. Arable farming can result in rapid wastage as it uses intensive drainage and cultivation (Morris et al., 2010).

Research has revealed arable farming has peat wastage of 10 to 30 mm/year from ploughing and drainage. In the East Anglia fens less than 60% of the remaining peat is less than 1 m thick, having an average depth of 70 cm. There may be only 25 to 50 years remaining life for arable farming there (Graves & Morris, 2013).

Widespread modification to support agriculture has resulted in agricultural lands on drained peatlands becoming one of the largest sources of greenhouse gas in the UK from land-use sector. The main control on CO_2 emissions is mean water table depth on lowland peat. CO_2 emissions increase by approximately 4 t CO_2-eq ha^{-1} yr^{-1} for every 10cm increase in water table depth. Therefore, having a higher mean water table on agricultural land can result in lower CO_2 emissions (Evans et al., 2016). Cropland is estimated to only be 7% of the peatlands area with emissions in total estimated at 7,600 kt CO_2e yr^{-1}, total of 32% of GHG emissions from peatlands (Evans et al., 2017). Agriculture on drained peatlands provide ecosystem services of food. This ultimately damages the peat and becomes a large source of GHG emissions. Representing a conundrum to policy makers of choosing food security and income for farmers or mitigation measures to reduce GHG emissions from peatlands restoration.

An important cultural service is on peatlands is recreation. Peatlands form some of the UKs most extensive wild spaces and a major tourist destination. The provision of visitor facilities is important, like car parks, visitor centres and paths. Bird-watching and fishing are important in the lowland peatland areas and walking in the uplands. In Scotland the remote rolling peatlands add to the Scottish experience for activities such as hill walking, gazing at the scenery and birdwatching. Walking on peatlands brings health benefits of physical exercise, refreshing the senses and may encourage calm reflection. Even the more unusual recreational activities like bog snorkeling bring in international visitors to our peatlands (Green Events, 2019). The Welsh Government (2015) identified the Bog Snorkelling Championships at Llanwrtyd Wells as contributing to the economic benefits of tourism in Wales in 2015.

Recreation is a very valuable ecosystem service on peatlands but remains poorly quantified. One of the main reasons is people are not always aware they are visiting a peatland site if data is being used to quantify recreation visits from survey methods. In addition, changes in visitor behaviour may be linked to the upland peat condition (Smyth et al., 2015). Rewetting resulting from restoration activities will affect popular recreational activities such as hill walking, horse riding or deer hunting, as this becomes increasingly difficult as the land becomes saturated for longer periods of time (Grand-Clement, 2013). For lowland sites the recreational value is usually easier to quantify and is linked to the peatland condition, an example being fens.

One such example of an easily accessible fen is the National Trust nature reserve at Wicken Fen, an area of around 358 hectares. Only about 1% of the original fen survives in East Anglia and this is a small part of it. It currently attracts 65,000 visitors to the reserve for a range of activities including walking, boat trips, school visits and the café. Restoration of the area has resulted in 48 km of public access being created or improved. The Wicken Fen Vision was a 100-year plan launched in 1999 to create a diverse landscape for wildlife and people to access for recreation. The aim being to increase the reserve to 53 km^2 (National Trust, 2019).

Another example of a peatland that has become popular with tourists is the 'Stairway to Heaven' at Cuilcagh Mountain in Northern Ireland. A boardwalk was built to protect the environmentally important sensitive peat bog from erosion. However, due to social media it has now become one of the top attractions in Northern Ireland as people want to share selfies from the 665m summit. Prior to its opening it 2015 it attracted less than 3,000 visitors a year. In 2016 this rose to 24,000 visitors and 70,000 in 2017 (Gray per comms, 2018). This increased popularity has threatened to damage the peatland the walk way was built to protect. The access is up a narrow road with only a small car park. The increased volume has resulted in parking on verges and blocking the roads. The car park can only accommodate about 30 cars, and hundreds of vehicles have been parked on verges along the road at weekends and on bank holidays. As a consequence of increased visits there is now erosion at the summit where people have strayed off the walkway.

Areas of remote peatlands can be of significance to recreation but due to their location attract low visitor numbers. One example of this the Flow Country in one of the least densely populated areas in the north of Scotland. The Flow Country has 10% of the UK's blanket bog and almost 5% of the world's resource. The Flows to the Future project is restoring 7 square miles of blanket bog that was once forestry. Improvements have included a new viewing tower, a board walk on an existing trail, interpretation on the trail, extra car park, updated the visitor centre and increased opportunities to volunteer at the RSPB reserve by building volunteer accommodation. It is estimated the Gross Value Added for this project over a 30-year period to be £6.3 million, giving economic benefit to one of the least densely populate areas in Scotland (Flows to the Future, 2019). Since building the viewing tower and short board walk visitor numbers have increased to 5,000 a year. Which is significant as to get there the only access is up a 27-mile single track road (Eccles per comms, 2018).

Sporting management in Scotland sustains deer stalking, grouse shooting and fishing enterprises. In the UK it is estimated 47,000 people take part in grouse shooting in upland areas (Morris et al., 2010). Grouse moor land management practices has led to regular burning of upland peat to provide patches young and older heather for nesting cover and food for the grouse. The vegetation changes to be more like a dry heath (JNCC, 2011). As a result of regular burning in England approximately 1,000 km^2 of deep peat has become like heathland (CCC, 2013).

Damaging land practices over decades have resulted in widespread degradation of peatlands, with most of the upland peat in England being acidified from atmospheric pollution. It is not wet enough for peat-forming vegetation to develop (CCC, 2013). In the UK it is estimated 95,000 ha of peatland have had a restoration intervention since 1990. With 70,000 ha being re-wetted. It has been estimated these restorations of peatlands has reduced emissions of 423 kt CO_2e yr^{-1} since 1990 (Evans et al., 2017). In England and Wales conservation managed lowland fens are one of the most effective carbon sinks (Evans et al. 2016).

7.3 Protected peatlands

Peatlands can have formal designations including Special Areas of Conservation (SACs) or a Site of Special Scientific Interest (SSSI) or Areas of Special Scientific Interest (ASSI) in Northern Ireland. It is an area of peatlands of interest to science that has rare fauna or flora present or important geological or physiological features. Wetlands with an international importance are also designated RAMSAR sites, usually designated for their water birds.

7.3.1 SACs, SCIs and cSACs

Special Areas of Conservation (SACs) are protected sites under the EC Habitats Directive (92/43/EEC). This directive requires the establishment of a European network of important conservation sites which make a significant contribution to conserving 189 habitat types and 788 species identified in the Annexes of the directive**.** Sites of Community Importance (SCIs) are sites that have been adopted by the European Commission but not yet formally designated by the government of each country**.** Candidate SACs (cSACs**)** are sites that have been submitted to the European Commission, but not yet formally adopted. There are a total 658 designated SACs, SCIs or cSACs in the United Kingdom as at December 2017 (JNCC, 2017).

In Wales there are 22,100 ha of peatland within SACs, with many of the sites undergoing significant restoration. This includes 15 peatland National Nature Reserves (NRW, 2018). In England 2,196 km^2 of deep peatlands contain internationally important wildlife or are of biodiversity interest, as Special Areas of Conservation (SACs) Special Protection Areas (SPAs) or Ramsar Sites (Natural England, 2010). Scotland has over 221,000 ha as designated SACs (SNH, 2015). The 1988 Northern Ireland Peatland Survey included 1,850 ha of lowland raised bogs and 10,000 ha blanket bog designated as SACs. Table 7.3 has the classifications for grading SAC sites and Table 7.4 is a summary of SACs with peat being an interest feature in the UK.

Table 7.3 Classifications of site grades for SACs (JNCC, 2018)

Explanation of grades	
A	Outstanding examples of the feature in a European context.
B	Excellent examples of the feature, significantly above the threshold for SSSI/ASSI notification but of somewhat lower value than grade A sites.
C	Examples of the feature which are of at least national importance (i.e. usually above the threshold for SSSI/ASSI notification on terrestrial sites) but not significantly above this. These features are not the primary reason for SACs being selected.
D	Features of below SSSI quality occurring on SACs These are non-qualifying features ("non-significant presence"), indicated by a letter D, but this is not a formal global grade

Table 7.4 Categories of SACs with peat in the UK (JNCC, 2018)

Category	Number
Active raised bogs	54
Degraded raised bogs still capable of natural regeneration	37
Blanket bogs	77
Transition mires and quaking bogs	41
Depressions on peat substrates of the *Rhynchosporion*	32
Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*	13
Alkaline fens	49
Bog woodland	17

Active raised bogs (Figure 7.5) are peat-forming ecosystems that have developed during thousands of years of peat accumulation, to such an extent that the depth of peat isolates them from the influence of groundwater. Typically, lowland raised bogs form a raised dome of peat irrigated solely by rainfall. Such rainwater-fed ecosystems are very acid and poor in plant nutrients and typically support a restricted range of species, some of which are otherwise abundant only in the cooler and wetter uplands of the UK. This is a priority feature for SACs (JNCC, 2018a).

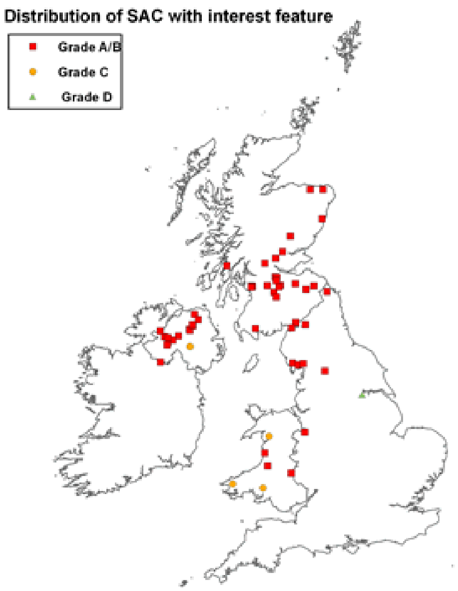


Figure 7.5 Distribution of SACs/SCIs/cSACs with habitat of Active raised bogs (JNCC, 2018a)

Degraded raised bogs still capable of natural regeneration (Figure 7.6) occur where there has been widespread disruption to the structure and function of the peat body. Disruption can mean changes to the vegetation, hydrology and the physical structure of the bog. This leads to desiccation, oxidation and loss of species or changes in the balance of the species composition. Degraded bog does not have peat currently forming (JNCC, 2018b).

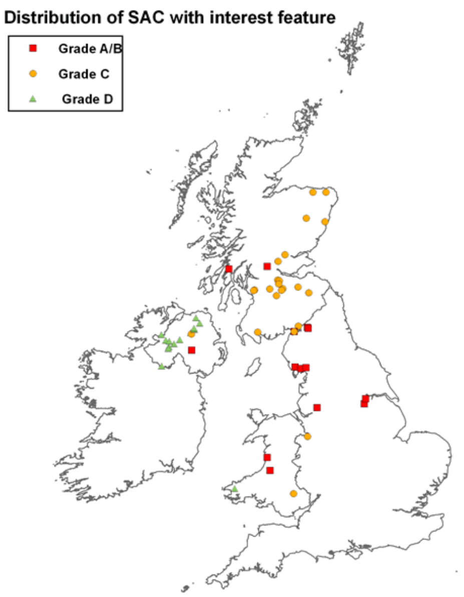


Figure 7.6 Distribution of SACs/SCIs/cSACs containing habitat of Degraded raised bogs still capable of natural regeneration (JNCC, 2018b)

Blanket bog (Figure 7.7) is an extensive area of peatland formed in climates of high rainfall and low levels of evapotranspiration. The blanketing of the ground in peat results in various morphological types according to their location, including saddle mires, valleyside mires and watershed mires. Climatic factors can influence the floristic composition of the vegetation. This is a priority feature for SACs (JNCC, 2018c).

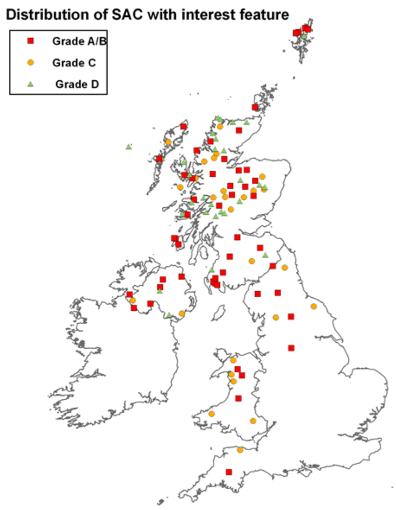


Figure 7.7 Distribution of SACs/SCIs/cSACs containing habitat of Blanket bogs (JNCC, 2018c)

Transition mires and quaking bogs (Figure 7.8) have vegetation that has general ecological characteristics between and acid bog and an alkaline fen. The mire can occupy a physical location between a bog transitioning to a fen. These systems are often unstable and can be described as 'quaking bogs' (JNCC, 2018d).

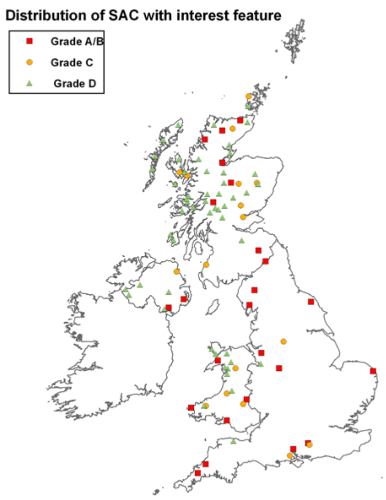


Figure 7.8 Distribution of SACs/SCIs/cSACs containing habitat Transition mires and quaking bogs (JNCC, 2018d)

Depressions on peat substrates of the *Rhynchosporion* (Figure 7.9) occur with lowland wet heath and valley mire vegetation in complex mosaics. They occur in transition mires, on the margins of bog pools and hollows in blanket and raised bog (JNCC, 2018e).

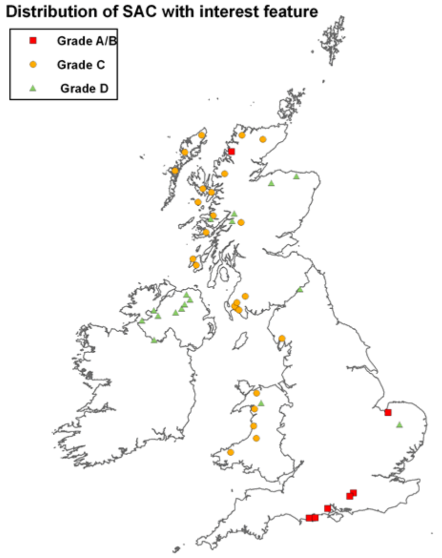


Figure 7.9 Distribution of SACs/SCIs/cSACs containing habitat of Depressions on peat substrates of the *Rhynchosporion* (JNCC, 2018e)

Calcareous fens (Figure 7.10) are rare in the UK with the two main areas being the Broadlands of East Anglia and the fen system on Anglesey. This is a priority habitat and site selection has favoured those sites where *Cladium* stands are most extensive (JNCC, 2018f).

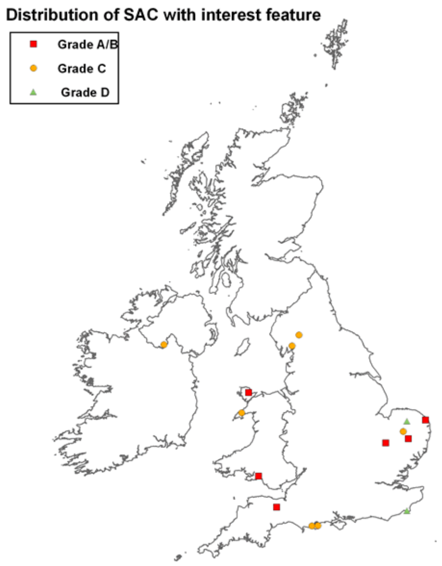


Figure 7.10 Distribution of SACs/SCIs/cSACs containing habitat of Calcareous fens with *Cladiumariscus* and species of the *Caricion davallianae* (JNCC, 2018f)

Alkaline fens (Figure 7.11) are characteristic of sites where there is tufa and/or peat formation with a calcareous base-rich water supply and a high-water table. The main vegetation is low-growing sedge around a mire. Important concentrations of this habitat are found in East Anglia, northern England and Anglesey. This vegetation has declined dramatically in the UK in the past century (JNCC, 2018g).

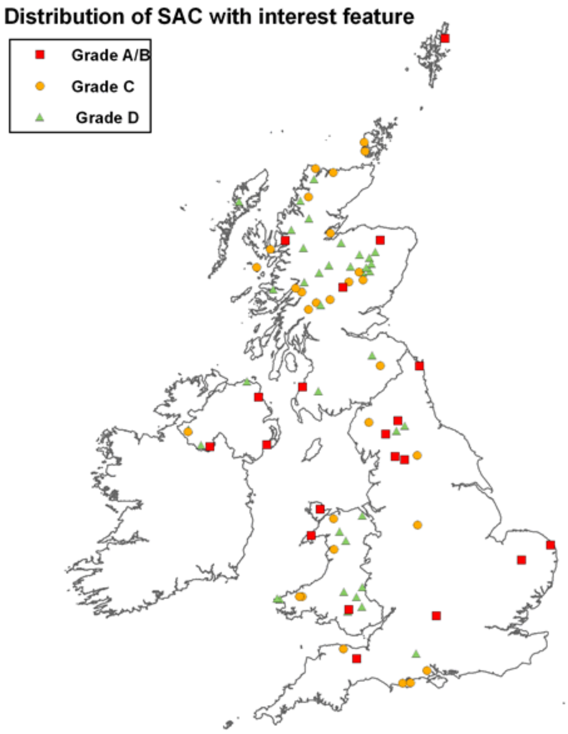


Figure 7.11 Distribution of SACs/SCIs/cSACs containing habitat of Alkaline fens (JNCC, 2018g)

Bog woodland (Figure 7.12) develops under certain combinations of physical circumstances in the UK, scattered trees can occur across the surface of a bog in a relatively stable ecological relationship as open woodland, without the loss of bog species. This true bog woodland is a much rarer condition than the progressive invasion of bogs by trees, through natural colonisation or afforestation following changes in the drainage pattern which leads eventually to the loss of the bog community (JNCC, 2018h). True bog woodlands are so rare in the UK they are on the UK red list of priority protected sites. They are rare enough to be excluded from ecosystem woodland accounts at present.

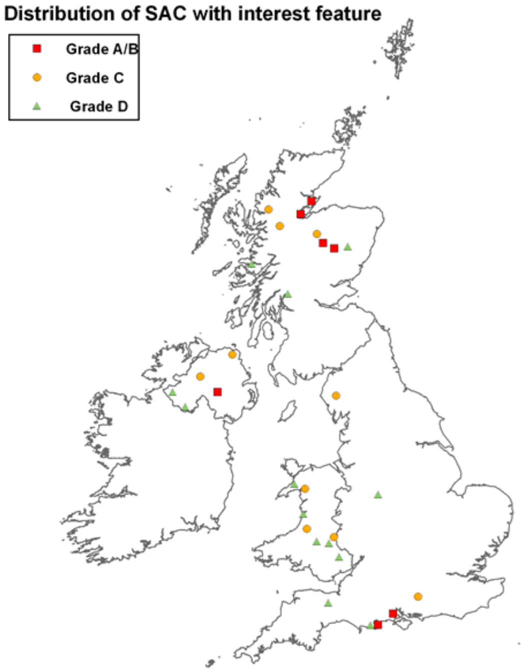


Figure 7.12 Distribution of SACs/SCIs/cSACs with habitat of Bog woodland (JNCC, 2018h)

Data in Table 7.5 is based on data for the period April 1998 - March 2005. The data were provided by the country agencies to JNCC in July and August 2005. The data was not available for Wales in the blanket bog category and there was not 100% return rate for the assessments of the SAC site condition (JNCC, 2011).

Table 7.5 Condition assessment of core peatland habitat features designated SACs in the UK (JNCC, 2006)

Reporting categories	Favourable	Unfavourable recovering	Unfavourable	Destroyed (Whole or part)	No. assessments reported	% returns	Regions
Blanket bog	45%	14%	39%	2%	66	65%	E,S,NI
Lowland raised bogs	19%	52%	29%	0%	79	81%	UK
Fens and marshes - upland	45%	19%	36%	0%	58	74%	UK
Fens and marshes - lowland	18%	39%	43%	0%	80	85%	UK

7.3.2 SSSIs and ASSIs

Sites of Special Scientific Interest (SSSIs) are areas that represent the best areas of natural heritage in terms of their fauna, flora, geology and landforms in Wales, Scotland and England. Northern Ireland has Areas of Scientific Interest (ASSIs) for natural heritage sites.

Some 2,478 km2 (36%) of England's deep peatlands are designated within Sites of Special Scientific Interest (SSSIs) (Natural England, 2010). In Scotland the total area of SSSIs that contain notified features associated with peatlands is 5.6% of the land area. In Northern Ireland 17 Areas of ASSIs have blanket bog as a feature, 28,000 ha, and 25 ASSIs for lowland raised bogs, 25,196 ha (NIEA, 2011). In Wales SSSIs on Peatlands include approximately 47,440 ha of deep peat with currently 13,500 ha included in current management plans. However, 70% of SSSIs are in unfavourable condition (NRW, 2018).

In England only around 160km^2 is in a good enough condition to be actively forming peat. Table 7.6 shows a decline in the area classed as 'favorable' SSSIs from 2003 to 2013 for deep peat blanket bog. There is an increase of SSSIs classed as 'unfavorable recovering', 85% of the blanket bog in 2013 from 16% in 2003.

Table 7.6 Condition of SSSIs for blanket bog deep peat in England (CCC, 2013)

Condition	2003 km^2	2013 km^2
Favourable	212	157
Unfavourable recovering	202	1115
Unfavourable no change	652	16
Unfavourable declining	237	18

Between 2011 and 2018 the protected sites areas classified as favourable for blanket bog, lowland fens and lowland raised bog in England has increased, however, upland flushes, fens and swamps has seen a decline in area for favourable, as shown in table 7.7. There has only been a small rise in peatlands habitats being classed as favourable, from 31,353 ha in 2011 to 33,656 ha in 2018. In the same period sites classed as unfavourable have risen from 6,893 ha to 12,862 ha of all sites.

Table 7.7 Condition of SSSI/SAC/RAMSAR sites in England 2011-2018 (NE, 2018)

		2011		2012		2014		2015		2016		2017		2018	
Habitat	**Condition**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
Blanket Bog	Favourable	23,685	13	24,421	13	24,995	13	25,121	13	24,061	13	25,700	13	25,325	13
	Recovering	159,967	85	159,807	85	158,622	85	157,406	84	156,407	84	156,092	82	155,814	82
	Unfavourable	3,588	2	3,011	2	3,622	2	4,713	3	6,771	4	9,688	5	9,774	5
Upland Flushes Fens & Swamps	Favourable	2,128	33	2,125	33	1,997	31	1,998	31	2,015	31	2,015	31	1,986	31
	Recovering	4,179	64	4,199	64	4,239	65	4,233	65	4,180	64	4,055	63	4,044	63
	Unfavourable	203	3	187	3	274	4	278	4	317	5	350	5	390	6
Lowland Fens	Favourable	5,144	39	5,136	39	5,696	43	5,701	43	5,782	43	5,834	44	5,855	45
	Recovering	6,587	50	6,571	49	6,201	47	6,273	47	6,176	46	6,041	46	5,885	45
	Unfavourable	1,545	12	1,572	12	1,383	10	1,303	10	1,339	10	1,269	10	1,326	10
Lowland Raised Bog	Favourable	396	5	385	5	470	6	386	5	579	7	492	6	490	6
	Recovering	6,313	76	6,212	75	6,438	78	6,025	78	6,473	77	6,506	78	6,519	78
	Unfavourable	1,557	19	1,672	20	1,362	16	1,322	17	1,328	16	1,393	17	1,372	16

As shown in table 7.8, all peatland habitat categories in Scotland showed an increase in the number of sites in favourable condition from 2007 to 2018. With the total number of favourable protected sites rising from 333 sites in 2007 to 428 sites in 2018, an increase from 58.1% of total sites to 69.8%.

Table 7.8 Condition of SSSIs, SACs and RAMSAR sites in Scotland (SNH, 2018)

		2018		2015		2010		2007	
Habitat	**Condition**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Upland bog	Favourable	128	67%	120	63%	116	61%	121	67%
	Unfavourable	34	18%	47	25%	55	29%	59	33%
	Unfavourable recovering due to management	29	15%	22	12%	18	9%	0	0%
	Not assessed	0	0%	2	1%	1	1%	0	0%
Wetland bog	Favourable	74	64%	69	60%	64	57%	33	31%
	Unfavourable	13	11%	26	23%	27	24%	75	69%
	Unfavourable recovering due to management	28	24%	20	17%	20	18%	0	0%
	Not assessed	0	0%	0	0%	1	1%	0	0%
Upland fen, marsh & swamp	Favourable	55	77%	49	69%	41	58%	34	53%
	Unfavourable	9	13%	10	14%	17	24%	30	47%
	Unfavourable recovering due to management	7	10%	12	17%	9	13%	0	0%
	Not assessed	0	0%	0	0%	4	6%	0	0%
Wetland fen, marsh & swamp	Favourable	171	72%	166	71%	155	65%	145	66%
	Unfavourable	36	15%	39	17%	42	18%	76	34%
	Unfavourable recovering due to management	27	11%	25	11%	22	9%	0	0%
	Not assessed	1	0%	3	1%	21	9%	0	0%
	To Be Denotified	1	0%	1	0%	0	0%	0	0%

Data in table 7.9 is based on data for the period April 1998 - March 2005. The data were provided by the country agencies to JNCC in July and August 2005. There was no data for Wales in any of the reporting categories and the return percentage was unknown (JNCC, 2006).

Table 7.9 Condition assessment of core peatland habitat features on SSSI/ASSI designated sites in the UK (JNCC, 2011)

Reporting categories	Favourable	Unfavourable recovering	Unfavourable	Destroyed	No. assessments reported	% returns	Regions
Blanket bog	58%	15%	27%	0%	156	unknown	E,S,NI
Lowland raised bogs	22%	35%	41%	2%	120	unknown	E,S,NI
Fens and marshes - upland	46%	18%	34%	2%	56	unknown	E,S,NI
Fens and marshes - lowland	41%	21%	37%	1%	709	unknown	E,S,NI

7.4 Physical condition

There are several well-established methods for assessing peatland habitat condition including Common Standards Monitoring, Phase 1 Habitat Survey and National Vegetation Survey. However, these are designed to be used by experts with good plant identification skills and expertise in the field.

The Peatland Code was developed as a voluntary standard to apply to peatland restoration projects to ensure deliverable benefits to mitigate climate change. It was developed so it is simpler and can be used by non-experts with appropriate guidance. When the code was developed it was important it was founded on robust scientific and economic valuations. The Peatland code identified different peatland conditions to establish the condition of peat bogs from pristine to actively degrading. In addition, it assesses the peatland habitat function, as this information can be used to calculate carbon budgets (Smyth et al., 2015). As the code was developed for restoration projects it does not cover all categories where peat is present in the UK. Currently there is no UK data for Peatlands on their condition using the Peatland Code.

Peatland Code Condition Category criteria:

- Pristine
    - Dominated by peat forming species (in most instances Sphagnum moss)
    - Never been modified by land use: drainage, grazing, burning, pollution
- Near Natural
    - Sphagnum dominated
    - No known fires
    - Grazing and trampling impacts scare or absent
    - Little or no bare peat
    - Calluna vulgaris absent or scarce
- Modified
    - Moderately degraded
        - Infrequent fires
        - Grazing and trampling impacts localised and infrequent
        - Sphagnum in parts
        - Extent of bare peat limited to small patches
        - Scattered patches of Calluna vulgaris
    - Highly Degraded
        - Small discrete patches of bare peat frequent (micro-erosion)
        - Frequent fires
        - Frequent and conspicuous impacts of grazing/trampling
        - No/little Sphagnum
        - Calluna vulgaris extensive

- Drained
    - Within 30m of an artificial drain (grip)
- Actively Eroding
    - Actively eroding hagg/gully system (most of their length having no vegetation in gully bottoms with steep bare peat "cliffs")
    - Extensive continuous bare peat (eg. peat pan)
    - Extensive bare peat at former peat cutting site

Peatland undisturbed by atmospheric pollution or management of the land by drainage, moorland burning or land use changes such as crops or forestry plantations is only a small part of UK peatland area. To assess peatland condition to cover different land uses Smyth et al. (2015) suggests a list of possible ecosystem condition indicators for peatland for use in greenhouse gas calculations, including:

- Bog - Near natural (vegetation not modified by human management)
- Bog – modified (could split into heather/grass dominated, and/or burnt/grazed)
- Bog – drained
- Bog – eroding
- Woodland – conifer – on peat
- Woodland – broadleaf - on peat
- Improved grassland on peat
- Cropland on peat
- Fen - near natural
- Fen – modified, scrub-covered
- Peat extraction
- Rewetted bog
- Rewetted fen

There currently is no data source that has condition of peatlands in the UK for a consistent reference year. The latest estimations on peatland condition categories is included in the Implementation of an Emissions Inventory for UK Peatlands project report, Table 7.10 (Evans et al., 2017). The approach was to use a map reference year and then estimate changes over time relative to that reference year. Figure 7.13 is the classification scheme used for the land categories used, which was based on the Intergovernmental Panel on Climate Change (IPCC) reporting categories. For Scotland a baseline year was established from the Land Cover Map for Scotland 1988 and this data was mapped using the classification scheme in Figure 7.13. Spatial data for England was taken from the Land Cover Maps for 2007, Natural England Report 257, the 2013 National Forest Inventory and the CEH Google Map-based inventory of peat extraction sites. The Wales land cover data was used from the NRW Phase 1 habitat survey. For Northern Ireland the Land Cover Map for 2007and the Northern Ireland Peat Survey was used as the dataset. All these datasets required modifying to fit in with the land condition categories. Full details on methods and assumptions used are detailed in the report (Evans et al., 2017).

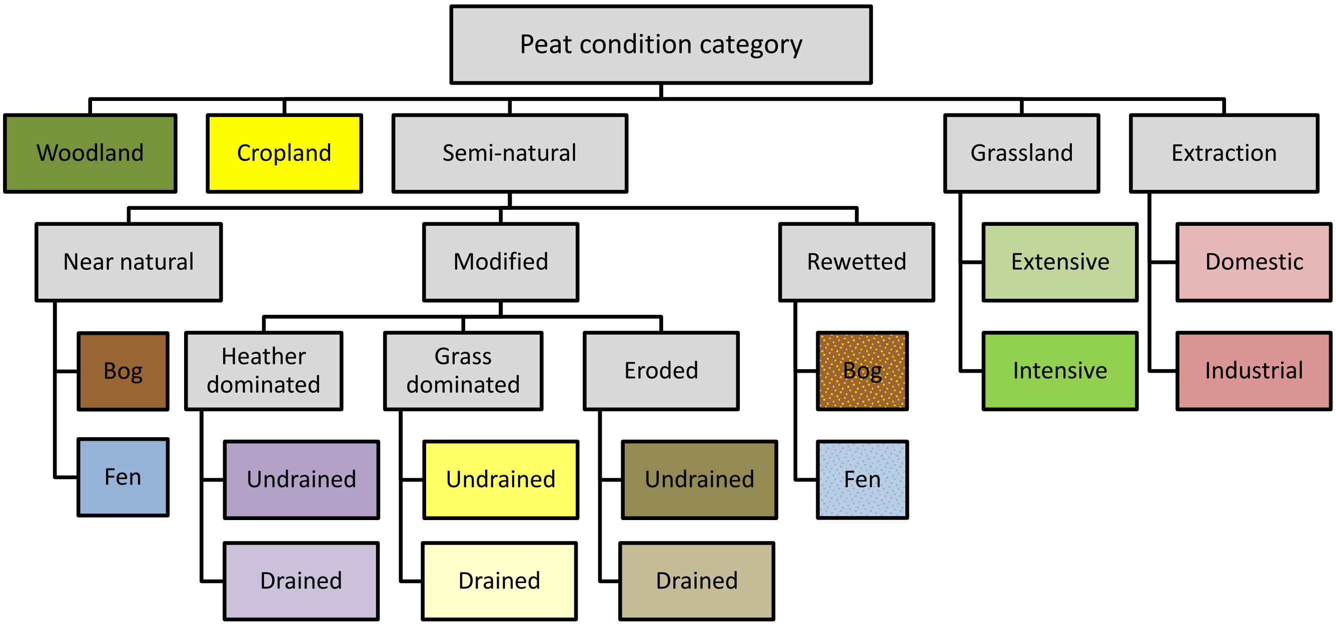


Figure 7.13 Land cover hierarchy classification scheme based on the Intergovernmental Panel on Climate Change (IPCC) reporting categories. Coloured cells have assigned Tier 2 emission factors, grey cells represent higher-level categories encompassing two or more sub-categories (Evans et al., 2017).

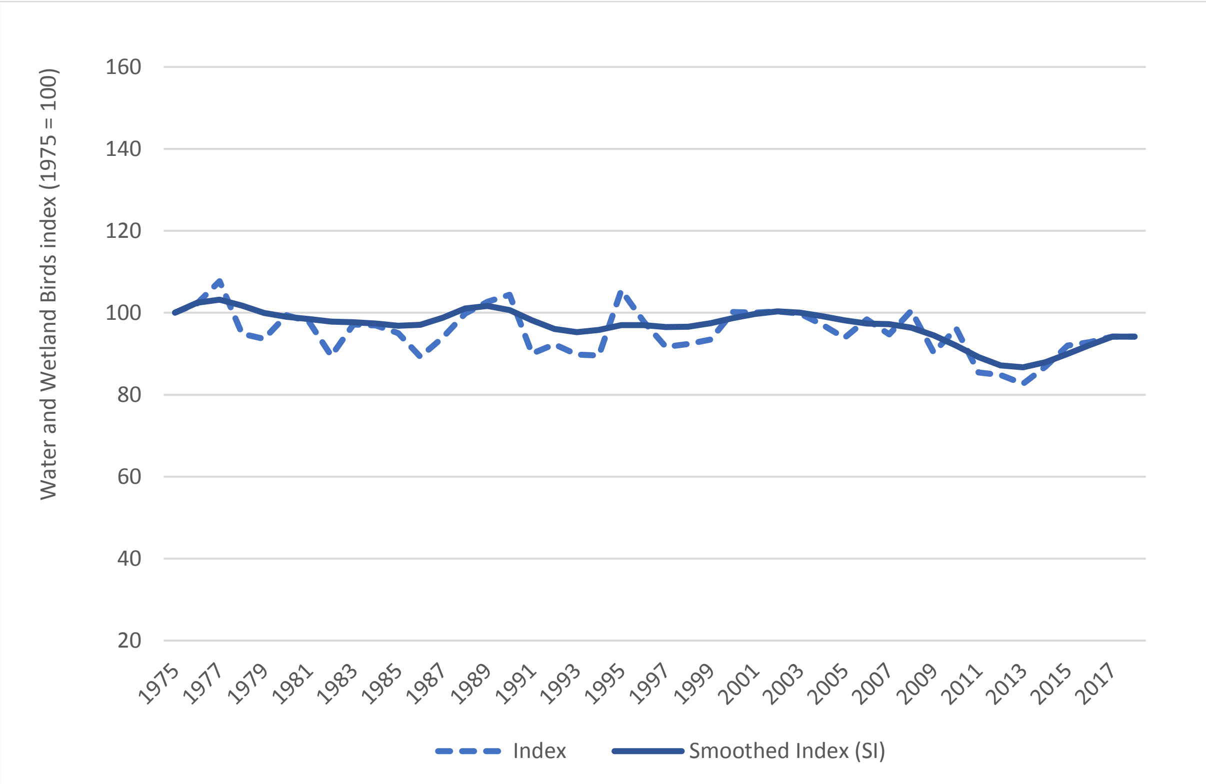
Table 7.10. Peat areas (ha) by condition categories for each UK administration for the reference year used (Evans et al. (2017).

Country	England		Scotland	Wales	NI
Peat category	**Deep peat**	**Wasted peat**	**All**	**All**	**All**
Data sources	LCM2007 NE257	LCM2007 NE257	LCS88	Phase 1 Habitat Survey	LCM2007 NI Peat Survey
	NFI2013	NFI2013			
Reference map year	**2013**	**2013**	**1990**	**1990**	**2007**
Forest	51,764	13,728	332,746	9,520	31,534
Cropland	50,594	132,107	8,181	102	3,141
Drained Eroded Modified Bog	5,653	0	75,147	19	2,170
Undrained Eroded Modified Bog	43,560	8	198,116	206	3,470
Drained Heather Dominated Modified Bog	19,208	0	155,196	1,588	6,667
Undrained Heather Dominated Modified Bog	87,166	55	409,154	6,237	10,702
Drained Grass Dominated Modified Bog	24,053	0	33,130	1,588	6,667
Undrained Grass Dominated Modified Bog	32,992	1,833	87,344	29,000	15,747
Extensive grassland	1,377	518	31,794	8,993	1,932
Intensive grassland	38,416	35,265	78,641	6,577	31,248
Near Natural Bog	83,930	2,348	490,497	23,548	35,915
Near Natural Fen	0	0	0	2,674	0
Extracted Domestic (fuel peat)	4,254	137	44,923	0	87,539
Extracted Industrial (horticultural)	4,627	1	2,881	0	525
Rewetted Bog	23,784	286	0	0	5,032
Rewetted Fen	24,451	86	0	0	334
Total	**495,829**	**186,372**	**1,947,750**	**90,050**	**242,623**

7.5 Wetland bird index

A good indication of the broad condition of wildlife in the UK is the bird population. Birds occupy a range of habitats and respond to environmental pressures. There is a wealth of long-term data available on birds making them suitable for long term trend analysis (Defra, 2018).

Wetlands includes fens, marshes, swamps and bogs which are generally peat environments. The water and wetlands bird index include rivers, lakes, ponds, reedbeds, coastal marshes and lowland raised bogs. The index measures 26 bird species. The species are selected if they have a population of at least 300 breeding pairs and are a native species. The water and wetland bird index has remained fairly stable since data collection started in 1975, however, it has been lowest in the last decade (Figure 7.14) (Defra, 2018).



Source: Department for Environment, Food and Rural Affairs (DEFRA) compiled data from the British Trust for Ornithology (BTO), Royal Society for the Protection of Birds (RSPB), Joint Nature Conservation Committee (JNCC) and the Wildfowl and Wetlands Trust (WWT).
Figure 7.14. Water and wetland bird index 1975 to 2017

7.6 Data issues

As there have been historic differences in the mapping extent of peatlands and different definitions of what is peat, numerous implications arise when trying to assess the current extent and condition of the peatlands in the UK.

Environmental policies and protection are devolved to the four administrative regions of the UK. In Northern Ireland The Department of Agriculture, Environment and Rural Affairs (DAERA) has responsibility for environmental and sustainability policy. DAERA defines peat habitats using the European Commission's Interpretation Manual of European Union Habitats. Under this classification they define active bogs as “still supporting a significant area of vegetation that is normally peat forming” (NIEA, 2012). Natural Resources Wales (NRW) was formed in 2013 and has responsibility for managing the environment and natural resources in Wales. In Scotland the responsibility for protecting natural assets is Scottish Natural Heritage, which was formed in 1992. In England it is the responsibility to Natural England (NE), formed in 2006, to protect nature and natural landscapes.

Issues that arise from devolved responsibilities for peatlands include not having a unified definition for peat and different policies when it comes to land management. An example of different policies being in relation to peat extraction, where in Northern Ireland it is still permitted to extract peat for use in horticulture and as fuel whereas in Wales there is no permitted extraction of peat.

Since the 1940s soils have been mapped by the National Soil Survey Institutes of the 4 administrative regions of the UK. Each part of the UK adapted the classification system describing the peaty soils. National peat depth definitions when it comes to mapping of peat extent are 40 cm depth in England and Wales and 50 cm depth in Scotland and Northern Ireland. There are soils classed as shallow peats which have a peaty organic horizon over mineral soil and are very extensive in the UK. However, they do not have the required peat depth to be included in the extent of peat as they do not match to the national definitions of what peat is. See JNCC (2011) report ‘Towards an assessment of the state of UK Peatlands’ for full details of the different soil classifications.

In addition to trying to assess the extent of peat there is also an issue trying to assess the condition of the peat. There are no comparable land cover maps from the different regions of the UK from different points in time. This combined with inconsistencies in classification of peat means there is currently no historical data existing to show change over time for peat condition in the UK (Evans et al., 2017).

The latest research from the Implementation of an Emissions Inventory for UK Peatlands (2017) identified significant discrepancies when identifying peat boundaries for the different UK administrations. Mainly between different soil types and peat on the various maps. This has the potential to lead to significant errors in estimations of extent and calculations based on estimated extent, such as GHG emissions.

Historically there has been an interest in peat depth due to the commercial value of peat as a horticultural product and as a fuel. Currently there is a lack of spatial understanding of the variations in the depth of peat in addition to their true extent. Attempts to estimate peat depth have assumed a uniform depth when estimating the amount of carbon stock in the UK. Natural England (2012) gathered information on peat depth from a variety of sources including survey data, academic publications and soil surveys. It was recognised that some of the data was over 25 years old, however, it was the best available information. Highlighting the need for a comprehensive national survey. To improve peat depth knowledge Scottish Natural Heritage (2017) have undertaken a project to better understand peat depth in Scotland. Results revealed an average peat depth across these sites of 2.18 m and a maximum depth of 18.8 m. Further work is required to determine the national picture. Forest Research (Vanguelova et al.,2012) identified the importance of accurate mapping which needs to be based on observation in the field when trying to assess the extent and condition of peatlands in Wales. To produce the map of peat resources in Wales data from the Habitat Phase 1 survey, National Soil Survey of England and Wales (NSRI survey) and the British Geological Survey dataset (BGS) were used.

This gap in knowledge on the depth of peat deposits makes it a challenge to calculate the total volume of peat and the carbon currently stored in it.

Devolved responsibility for environmental data has resulted in data sets not being compatible across the UK. In some cases, the data needed to calculate natural capital accounts does not exist or inaccessible for some regions. This makes it a challenge to present compatible data across the four administrative regions of the UK. As shown in section 7.3.2 when looking at SSSI data, Scotland has the data by number of sites and England by hectares.

7.7 Extent and condition discussion

Peatlands are a unique ecosystem recognised internationally for their importance and cover around 12% of the UK land area. In the UK they are the source of a significant amount of drinking water and estimated to store over three billion tonnes of carbon. Despite being an important habitat, it is estimated 80% of the UKs peatlands are in a damaged and deteriorating condition because of human activity. Including extraction for horticulture and fuel and drained for agriculture and forestry plantations.

To determine the ecosystem services provided by peatlands it is important to have data on the extent and condition of the peat. Peat in a good condition provides better quality ecosystem services. The natural capital accounts developed in the next section of the report are based on the latest available data on extent and condition of Peatlands. There are data gaps, with some of the data used being over 25 years old and no consistent data is available for the same time point throughout the UK.

These accounts use the data from the first UK-wide inventory of peatlands on the extent and condition of the peat (Evans et al., 2017) to inform the benefits peatlands provide to society. The development of future natural capital accounts will benefit from improvements in gathering data on the location and condition of the peat.

8. Ecosystem services

Peatlands provide a wide range of services that benefit people. This section summarises the main services that the peatlands provide. It is only a partial picture as it is not currently possible to capture all off the services provided and attribute a monetary value. The ecosystem services presented are split into provisioning, regulating and cultural.

8.1 Provisioning

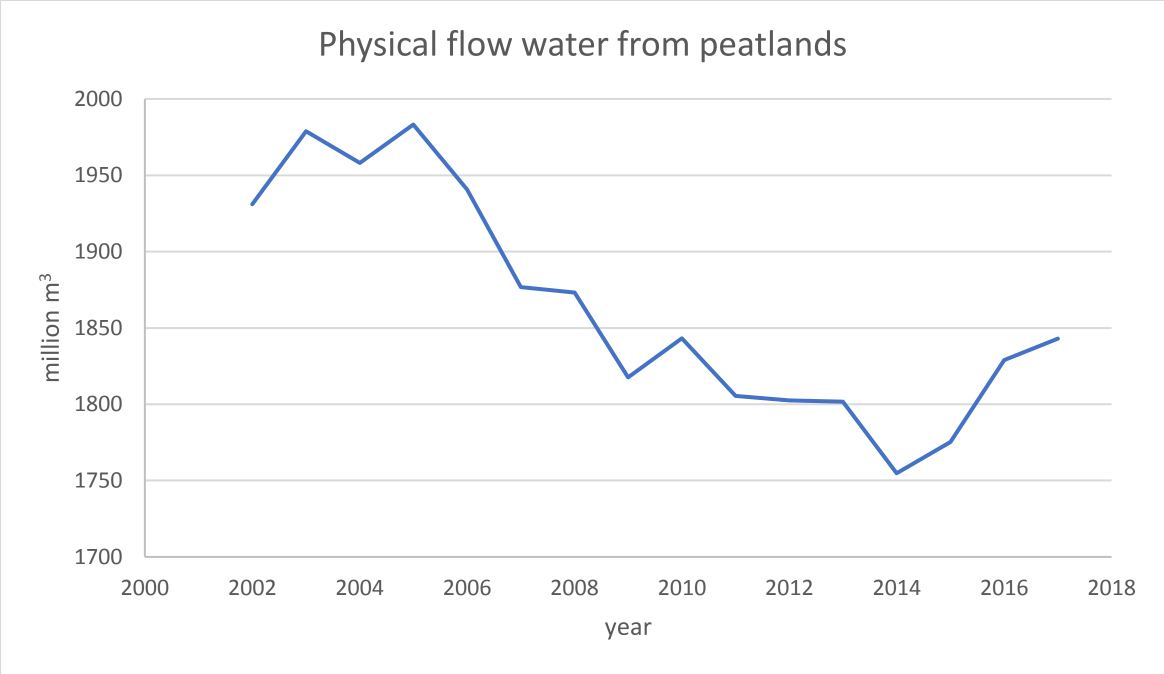
Provisioning ecosystem services create products. Within Peatlands these include fresh water, food, fibre and energy sources. The services provided vary significantly across different peatlands. For instance, fen peatlands have been drained and provide very fertile land for high value agriculture; whereas the upland blanket bogs are used for rough grazing (Bonn et al., 2009).

8.1.1 Water supply

Peat is dominant in the higher grounds and so a significant proportion of the UK's water supply lands or flows through peatlands. It is estimated 70% of the drinking water as a whole comes from upland areas (Scottish Forum on Natural Capital, 2016; IUCN, 2018c).

In the UK water abstraction for the public water supply peaked in 2005 at 1983 with the apportioned figure for water from peaty catchments at 1,983 million m^3, see figure 8.1. A possible reason for the decline from 2005 is more efficient and sustainable use of water, as advocated in the Water Act 2003. As a result, fewer licences have been granted for water abstraction in England and Wales, with fewer being issued annually in the last decade than between 1997 and 2002.

To ascertain values for water supply from UK peatland, these accounts have been apportioned from the ONS UK Ecosystem Service accounts. We can only make rough approximations. The extent of blanket bog in Scottish Water catchments was estimated to be 13.7% by SNH (Artz et al., 2014). For England and Wales, the area was calculated by working out the percentage the uplands which are peatlands then then taking 70% of this to estimate drinking water from peatlands, with England as 32.1% and Wales as 5.9%. Data was not available for Northern Ireland, so the same percentage was used as Wales since this was the lowest and most conservative figure.



Sources: Scottish Government, Natural Resources Wales, Department for Environment, Food and Rural Affairs, Drinking Water Inspectorate (Northern Ireland)
Figure 8.1 Water abstraction representing Peatlands

In total, based on the described apportionment, water from peatlands represents 27% of the UK ecosystem service accounts. We can then estimate the volume of supply from peat catchments, see Figure 8.1. It is accepted that water from peatland catchments has a different capital infrastructure and different cost to water supplies in lowland regions. If non-peat dominated water catchments are more or less expensive to run then our apportioning of economic figures will be inaccurate. We will be considering alternative approaches in the future to provide a more pertinent representation of the cost of water in peat catchments.

Annual monetary estimates are based on resource rents calculated for the Standard Industrial Classification (SIC) subdivision class: Water collection, treatment and supply. The resource rent can be interpreted as the annual return stemming directly from the natural capital asset itself, that is, the surplus value accruing to the extractor or user of a natural capital asset calculated after all costs and normal returns have been considered (see methodology section for full details). The annual value fluctuates between 2002 and 2016, with a low value in 2002 of £208 million and a high in 2016 of £888 million (Table 8.1).

Table 8.1 Estimated Value of UK drinking water from Peatlands

Year	Annual value (£m)	Asset value (£m)
2002	208	4,372
2003	274	4,814
2004	227	5,359
2005	344	6,643
2006	359	8,457
2007	263	8,754
2008	553	10,473
2009	480	12,005
2010	486	12,834
2011	527	13,811
2012	632	16,003
2013	632	16,442
2014	510	16,682
2015	392	16,111
2016	888	18,366

Source: ONS

8.1.2 Peat extraction

Extraction of peat continues in Northern Ireland, Scotland and England, mainly for horticultural use (IUCN, 2014). Extracted peat has contributed to the economy, however, the extraction of peat results in loss of the peat resource and carbon emissions. It is estimated total GHG emissions from sites where extraction has taken place is around 1,200 kt CO_2e yr^{-1} from domestic extraction sites, with higher emissions from industrial sites (Evans et al., 2017). The peat which has been extracted will eventually be oxidized to CO_2, creating an additional emission source. As can be seen from Table 8.2 peat extraction between 1997 and 2015 peaked in 2003 with 2,008,000 m^3 extracted. The total income generated from the peat extraction has an underlying trend declining from £119.0m in 1997 to £36.2m in 2015 with a peak in 2013 of £74.7m, based on 2017 prices (Table 8.2). The quantities extracted and income from peat extraction is expected to continue to decline as the UK Government has stated in the 25-year Environment plan (2018) an action to cease using peat in horticultural products by 2030.

Table 8.2 Peat extracted by volume and income

Year	Peat (m^3)	Total Income (£m, 2017 prices)
1997	1,619,000	119.0
1998	1,076,000	72.9
1999	1,653,000	101.2
2000	1,626,000	100.9
2001	1,814,000	114.0
2002	973,000	59.3
2003	2,008,000	108.3
2004	1,262,000	68.2
2005	1,505,000	93.8
2006	1,593,000	76.1
2007	885,000	40.6
2008	760,000	42.2
2009	887,000	47.4
2010	1,004,000	48.2
2011	825,000	42.7
2012	568,000	33.0
2013	1,254,000	74.7
2014	795,000	44.7
2015	800,000	36.2

Source: BGS Minerals yearbook (2015 data is an estimate) & ONS

Evans et al. (2017) estimated changes in peat extraction area over time (Table 8.3). Data from the LULUCF inventory on peat extraction sites and changes in sites registered in the Directory of Mines and Quarries (BGS) were assessed using Google Earth imagery from 2002. Earlier data was obtained from planning consents for 1991. Domestic extraction refers to peat cutting on blanket bog for fuel and industrial extraction on fen and raised bog peat for horticultural use. A small amount is also extracted for the whisky industry. As this data is area and not cubic metres it makes it difficult to compare to the BGS extraction rates. There is no extraction depth data.

Table 8.3 Area (ha) of industrial and domestic peat extraction sites by country in 1990 and 2013 (Evans et al., 2017)

Activity	Year	England	Scotland	Wales	N. Ireland	Total
Industrial extraction	1990	7,082	2,881	0	761	10,724
	2013	4,628	2,840	0	503	7,971
Domestic extraction	1990	4,402	44,923	0	92,202	141,527
	2013	4,391	44,649	0	87,539	136,579
Total	1990	11,484	47,804	0	92,963	152,251
	2013	9,019	47,489	0	88,042	144,550

8.1.3 Food

Livestock grazing is one of the most common land uses for peatlands (Bruneau & Johnson, 2014). Sheep can be farmed in almost every part of Wales due to their hardiness. In the uplands this may be the only feasible option. However, there are relatively low returns to the farmer despite having low maintenance and capital costs. Most livestock holdings in Wales are in Less Favoured Areas (LFA) (Welsh Government, 2018), an area of. 1.53 million hectares (RSPB, 2012). In Scotland the land quality for agriculture is quite poor with over 5.73 million hectares classed as LFA. As a result, most of the agriculture is livestock grazing, with 3.6 million hectares classified as rough or common grazing (Scottish Government, 2018).

In England around 240,000 ha of drained lowland peat is used for farming and food production with the east of England having high value cropping (Morris et al., 2010). The Fenland peatland accounts for approximately 10% (133,000 ha) of the national areas given to potatoes, sugar beet and vegetables (Graves & Morris, 2013). The NFU (2019) estimated the Fens produces more than 7% of the total of England's agricultural production, which was valued at £1.23bn.

The area of peatlands that has been drained for use as cropland is currently estimated as 194,124 ha in the UK (7% of total peat area), with 182,701 ha being in England (Evans et al., 2017). Using peatlands for drainage-based agriculture (horticulture, arable and intensive grassland) has a negative impact on the peat. There is an estimated peat wastage of 10 to 30 mm/year from arable farming on peat from drainage and ploughing (Graves & Morris, 2013). It is estimated 7,600 kt CO_2e yr^{-1} emissions from croplands on peatlands, total of 32% of the GHG emissions from peatlands (Evans et al., 2017).

The estimate for agriculture on peatlands is derived from the different land uses data calculated by CEH (Evans et al., 2017), data on area high value crops in the fens (Graves & Morris, 2013) and data from the Farm Business Survey (FBS). The FBS is an annual survey commissioned by Defra and uses a sample of farms that represent the national population, with a sample size around 2,300 farms in England and Wales. This is not sampled by soil types, so includes all soils not just peat. The FBS provides data for England on the outputs from agriculture excluding subsidies, costs for agriculture excluding Agri-environment activities and data on the total farmed area. A rate is then calculated per hectare and applied to the different land use classifications used by CEH. The rate calculated is for England and applied to the whole of the UK. Further work is needed to calculate a £/ha rate for the rest of the UK as the data is only currently available by £/farm. Table 8.4 shows horticulture has a positive contribution, however, overall there is a negative contribution to ecosystem services for agriculture.

Table 8.4 Summary peatlands used for agriculture 5-year average 2013/14-2017/18

CEH classification	Agriculture land use	ha	£/ha	Total £
Cropland	Horticulture	133,000	556.2885	73,986,366
	Arable/cereal	61,125	-12.8161	- 783,385
Modified Bog	sheep	560,703	-79.3779	- 44,507,445
Heather modified bog	sheep	695,973	-79.3779	- 55,244,897
Grassland	Grazing livestock/hay	234,761	-89.0907	- 20,915,014
Total		1,685,562		- 47,464,375

Source: CEH, ONS

The Farm Business Income by type of farm in England (Defra, 2018b) reveals LFA Grazing Livestock farms failed to make a positive return in 2017/18 (see Table 8.5 for selected farm types, full list in Defra report), with a higher average loss than in 2016/17. The value per farm for agriculture was -£12,500 with Agri-environment payments of £12,000. In addition, they had an average of £25,900 per farm from the Basic Payment Scheme, an EU rural grant payment. The farms, in aggregate, were only profitable as a result of subsidies. In comparison, Horticulture farm agriculture income is £26,700 with Agri-environment subsides of £1,200 and Basic Payment Scheme of £4,600 per farm. The horticulture farms total farm business income being £47,700 per farm (Table 8.5).

Table 8.5 Farm Business Income by farm type and cost centre (£/farm)

Farm type	Agriculture	Agri-environment payments	Diversified income	Basic Payment scheme	Farm business income
Cereals	1,600	3,800	18,700	40,200	64,200
General cropping	16,000	8,800	20,600	47,900	93,300
Grazing livestock (lowland)	-6,100	3,400	8,400	16,500	21,900
Grazing livestock (LFA)	-12,500	12,000	2,900	25,900	28,300
Horticulture	26,700	1,200	15,200	4,600	47,700

Source: Defra

There is a high degree of variability between income from different crops. According to the John Nix Pocket book for Farm Management 2019 (Redman, 2018) Gross Margin per hectare at the average price for wheat is £791, potatoes £1534 and sugar beet £760. With high variability on the income from different crops and lack of data on specific crops on peatlands a more accurate valuation may be feasible with further research.

8.1.4 Timber

In the UK total area of forestry in 2019 was 3.19 million ha (Forest Research, 2019b). The total area for forest on peatlands is 439,292 ha for the UK, 15% of the area of total peatlands and 14 % of the total forestry area. Research by CEH assessed the change in areas of afforestation on peat based on data from the Forestry Commission on grant assisted planting and deforestation from area of restored peat which was formerly forest, see Table 8.6. However, this data does not reflect changes in forestry policy which has encouraged tree removal on peat. It does reflect the general decrease in the rate of afforestation from 1,086 ha in 1990 to 83 ha in 2015 for the UK (Evans et al., 2017).

Table 8.6 Area of afforestation and deforestation on peat between 1990 and 2013 (Evans et al., 2017)

Activity	England ha	Scotland ha	Wales ha	Northern Ireland ha	Total ha
Afforestation	411	24,348	76	3,930	28,766
Deforestation	1,503	2,857	331	0	4,692
Net change	-1,092	+21,491	-255	+3,930	+24,074

Source: CEH

Historically the uplands had a significant expansion of woodlands to create a reserve of timber for national security. This started with the formation of the Forestry Commission in 1919. Recently forestry on peatland has been realised as ecologically undesirable or economically unviable (Bonn et al., 2009). Research by Walker et al. (2008) revealed in lowland peatlands tree and scrub removal was common. It was usual for the materials removed to be left on site to create onsite features such as boardwalks and unusual for timber to be taken off-site.

Timber grown on peatland tends to be less valuable and less productive than timber grown on different soils. It is difficult to extract timber from peatland as extraction costs can be high due to machinery getting bogged down and large areas can be affected by wind-blown damage (Smyth et al., 2015). Approximately 84,000 hectares of afforested peat is with low productive trees (CCC, 2018). Often the wood goes for pulp, fuel and other low grade uses as the timber from bogs is of poor quality (Sloan et al., 2018). It can cost more to remove trees from peatlands than the value of the timber. A study by Okumah et al. (2019) investigated different restoration costs for peat including the felling of trees to waste cost, which has a mean of £1993/ha. Data was only available for one site on normal-age forestry harvesting at £4306/ha. A previous study (Artz et al., 2018) revealed an average cost of £1,480/ha for harvesting normal-age forestry. This study showed there is considerable variation of costs between sites due to different site characteristics, such as accessibility.

Decisions need to be taken now as existing forests on peatlands come to harvesting age to either restore bogs or restock. Data is needed on the yields and quality of afforested peatlands in the UK to assess any ecosystem services benefit from timber (Sloan et al., 2018). The future of peatland plantations requires trades offs against biodiversity, value of commercial forestry and ecosystem services provided by the different habitats. There are conflicting issues for government to meet targets for extensive peatland restoration and forest expansion (Payne et al., 2018). Currently there is no data on the volume and value of timber from peatlands, only on total amounts of timber harvested.

8.1.5 Wind power

The main criteria for the location of a wind turbine is there needs to be wind with an average speed of 7ms-1 or greater (Bonn et al., 2009). Not the substrate they are built on. For windfarms on peatlands there is an important balance between the carbon savings from the windfarm and the loss of carbon sequestration and storage from the peat due to construction (Lindsay, 2010). Wind farms on peatlands have a potential for a range of negative impacts. This includes changes to hydrology caused by the building of access tracks with this also impacting on biodiversity and slope stability (Bonn et al., 2009). Many of the impacts from windfarms are not fully understood on peatlands.

In 2010 it was estimated most windfarms sites on peatlands had potential to reduce net emissions. However, by 2040 most sites will not reduce carbon emissions even with careful management. This is because of projected changes in the amount of fossil fuel used to generate electricity (Smith, Nayak & Smith, 2014). The Scottish Government (2018b) uses a carbon calculator tool to assess the carbon impact from wind farm developments. It looks at the carbon savings from the windfarm and compares against the carbon costs of a wind farm development.

Table 8.7 shows the number of operational turbines in Scotland for 2014 and the depth of the peat they stand on. Currently there is no data on total number of wind turbines for the UK on peatlands. However, Table 8.8 shows the number of wind turbines on the Mountain, Moorland and Heath (MMH) habitat for 2018. Details on GWh generated can be found in the MMH Natural capital publication (ONS, 2019). Further work is needed to identify all windfarms on peatlands. This can be achieved when a digital map of the area of peatlands is available to overlay with the windfarm location data from BEIS.

Table 8.7 Number of operational wind turbines in Scotland (2014 data) in relation to peat depth (Artz & Chapman, 2016)

Depth of peat/ organic matter (m)	Number of turbines in wind farm development <50MW	Number of turbines in wind farm development ≥ 50MW
0	708	264
>0.0-0.5	396	283
>0.5-1.0	131	192
>1.0-1.5	104	295
>1.5-2.0	21	1
>2	76	60
Total	1436	1095

Table 8.8 Number of wind turbines on Mountain, Moorland and Heath habitat by Land Cover Map 2015 classifications for 2018

LCM2015 habitat	**No. turbines**
Heather grassland	601
Heather	456
Bog	693
Fen, marsh and swamp	19
Inland rock	3
Total MMH	1772

Source: BEIS

8.2 Regulating

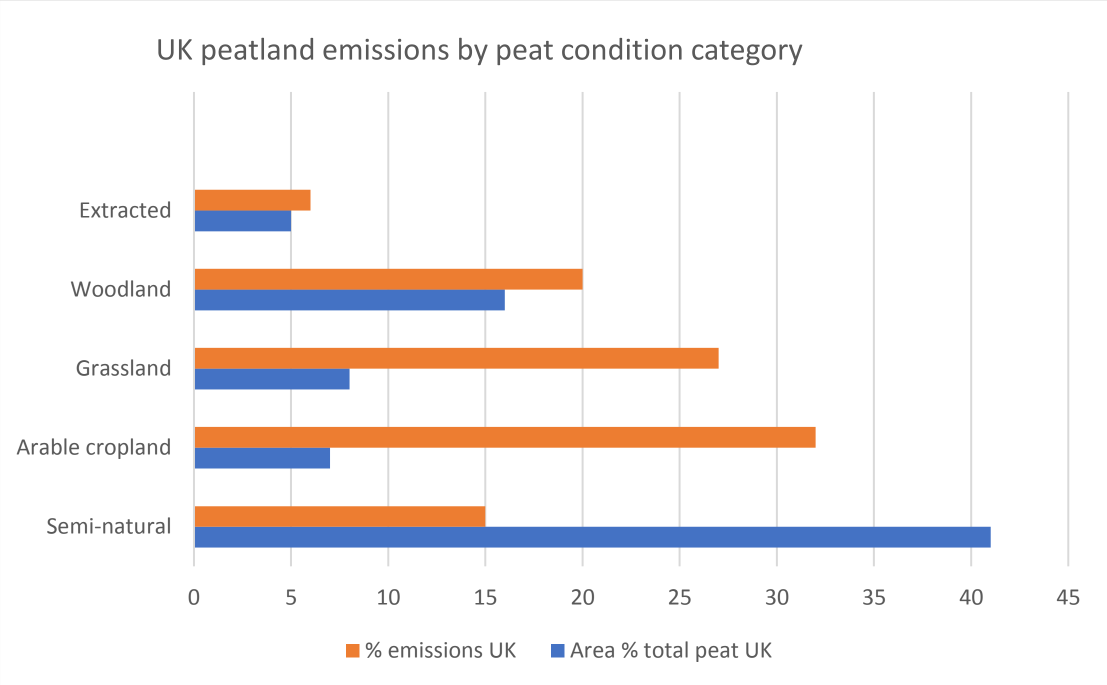
These are the benefits provided by the regulation of natural processes. Including air quality regulation, climate regulation, water quality and natural hazard regulation such as flooding and wildfires (Bonn et al., 2009).

8.2.1 Climate regulation through carbon storage

Peatlands can store a significant amount of carbon and is an import 'stock' value for the UK. However, this cannot be currently accurately measured or valued (Smyth et al., 2015). Data is available on the amount of carbon being sequestered from near natural fens and bogs. A near natural bog can remove 3.54 tCO_2 $ha^{-1}yr^{-1}$ and a near natural fen 5.44 tCO_2 $ha^{-1}yr^{-1}$ (Evans et al., 2017). Peatlands can also be a source of methane due to their waterlogged nature. Methane has a potential higher effect on global warming as it is a stronger greenhouse gas than CO_2, but it also has a shorter lifetime in the atmosphere which limits its impact. Over the long term the climate cooling effects of CO_2 sequestration by growing peat outweighs the warming impacts of the methane emitted. When methane and nitrous oxide are included near natural bog has small emissions of 0.01 tCO_2e $ha^{-1}yr^{-1}$ and near natural fen sequesters at 0.61 tCO_2e $ha^{-1}yr^{-1}$ (Evans et al., 2017). A peatland in a good water-logged condition can grow at around a rate of 0.5 to 1mm per year (IUCN, 2014b).

Currently there is only around 640,000 ha (22%) of peatlands in the UK that are in a near natural or rewetted state. It is estimated this area acts as a carbon sink with approximately 1,800 kt CO_2 yr^{-1}. When looking over the longer term near natural peatlands are close to climate neutral as there are emissions of methane which counterbalance the CO_2 sink, making them a very small net GHG sink. The remaining 78% of peatlands are in different states of degradation, which either reduces their capacity to sequester carbon, or turns them into (potentially very large) carbon sources. Overall, this has led to peatlands becoming a large net source of emissions. Recent research by CEH for BEIS estimates emissions from peatland sources to be around 23,100 kt CO_2e yr^{-1} (Evans et al., 2017).

The type of disturbance on the peatlands does result in a significant variation in the amount of emissions. Lowland peat that has been drained for crops emits around 32% (7,600 kt CO_2e $^{yr-1}$) of the total of UK peatlands emissions even though it only accounts for 7% of peatland area (see figure 8.2). Semi-natural peatlands making up 41% of UK peatlands area emits around 3,400 kt CO_2e yr^{-1}, around 15% of total peatland emissions. The majority of woodlands on peatlands are drained conifer plantations (Evans et al., 2017).



Source: CEH

Figure 8.2 Share of UK peatland emissions and peatland area by land type (Evans et al., 2017)

Table 8.9 Peatland CO_2 sink/emissions for the UK by land type (Evans et al., 2017)

Land use	**Area % total peat**	**CO_2 sink/emissions**
Near-natural	22	1,800 kt CO_2 yr^{-1}
Semi-natural	41	3,400 kt CO_2e yr^{-1}
Arable cropland	7	7,600 kt CO_2e yr^{-1}
Grassland	8	6,300 kt CO_2e yr^{-1}
Woodland	16	4,600 kt CO_2e yr^{-1}
Extracted	6	1,200 kt CO_2e yr-1

As Table 8.9 shows peatlands only near-natural peatlands are a sink of carbon and those that have been modified in the UK are emitting greenhouse gases and the resulting ecosystem flow would be counted as negative. On the other hand, any measures to reduce these emissions through changes in land-use and management have the potential to contribute significantly to meeting overall GHG emissions targets and thus contributing to climate change mitigation.

Smyth et al. (2015) suggests one method to include climate regulation from peatlands in the ecosystem services is to look at the reductions in emissions over time from peatland restoration projects. Currently around 80% of peatlands are in a degraded state and contributing to GHG emissions. Any improvements in peatland management would result in fewer emissions and therefore could be shown in the accounts as a reduction in emissions.

8.2.2 Water quality regulation (waste detoxification)

Peatlands in upland areas play a significant role in the supply and the quality of drinking water. The deep peats intercept and retain a range of atmospheric pollutants, including nitrogen, sulphur and heavy metals, providing less contamination in drinking waters. As a result, water from functioning peatlands is naturally of high quality (Committee Climate Change, 2013). The condition of the peatlands has an impact on the downstream catchments for the quality and quantity of water supplied. This impacts the value of the water for uses such as drinking water quality, agricultural uses and recreation uses on streams and rivers.

The Committee on Climate Change (2013) identified in England that there are increasing amounts of carbon being lost into water bodies. Levels of dissolved organic carbon (DOC) in water courses has doubled over the last 30 years. In upland areas this increase, which has been attributed to ecosystem recovery from the effects of acid rain (Monteith at al., 2007) has been responsible for the largest change in water quality in upland drinking water supplies. The erosion of upland peat is also releasing contaminants that were previously locked away in the peat. In addition, the transportation of particulate organic carbon due to peat erosion is reducing water storage capacity in reservoirs. See the MMH Natural Capital publication for further details of DOC levels (ONS, 2019).

The removal of peat sediment and dissolved organic carbon represents a large cost in water treatment for water utilities for water draining from degraded peatlands. Northern Ireland, Republic of Ireland and Scotland are working on the Co-operation Across Borders for

Biodiversity project (2017 – 2021) to restore peatlands to reduce runoff and improve quality of raw water, resulting in cost savings at the treatment works from the reduction of chemicals to remove the colour from the water (Northern Ireland Water, 2017).

NERC and Scottish Water are currently funding a large project (FREEDOM) to improve understanding of the relative importance of peatland management. Atmospheric deposition and reservoir processes in determining DOC levels in raw water supplies, and to develop a modelling system to support catchment-management and treatment infrastructure investment decisions.

DOC is problematic for the water treatment process as water companies must ensure they meet the environmental standards and regulations, including the EU Water Framework Directive 98/83/EC on the quality of water for human consumption.

Smyth et al. (2015) identified water quality regulation an important ecosystem service, however, measuring the physical flow is challenging. Suggestions for measuring this service included using catchment specific data on the costs of treating water for public supply. Numerous water companies within the UK are now undertaking restoration projects in their water catchments with the aim of improving water quality. Measuring the improvement in water quality would show a reduction in the negative impact from peatland degradation. An example is Scottish Water where they identified approximately 50% of their catchments contains peatland. They are now working on improving water quality upstream to reduce operational costs of treatment downstream (Rezatec, 2019).

Further research is needed to understand the complex water regulating services from peatlands.

8.2.3 Flood hazard regulation

The impact of peatland in a good condition on flood hazard regulation is not fully understood. Peatlands have the ability to store large volumes of water, as much as 90-98% water by mass when saturated. The storage capacity of peat led to a mistaken belief that they can diminish the impact of flooding by storing excess rainwater (Holden, 2005). The water storage capacity of upland wetlands and their influence on flooding downstream varies depending on the size of the wetlands relative to the drainage network (Heathwaite, 1995). For a reduction in flooding the water level in the wetland needs to be low enough to leave the capacity to store water rapidly. With most bogs close to saturation they are rarely able to attenuate flow and more likely to contribute to storm runoff as they are already saturated (Acerman &Holden, 2013).

The condition of the peatland, such as near natural or damaged, impacts on the speed of surface runoff and the size and timings of water flows in a river catchment, thus influencing amount of flooding (Smyth et al., 2015). Natural and restored peatlands provide reduced downstream flood risks compared to damaged peatlands (Committee Climate Change, 2013).

Further work is needed to quantify the regulation of water flow from peatlands during a flooding events for it to be included as an ecosystem service. Forest Research (2019b) has undertaken initial estimation of flood regulating services for GB woodland by investigating the equivalent to effective flood water storage that would need to be provided if the woodland cover absent and replaced by grassland. A similar approach on peatlands could adopt an equivalent storage capacity approach. If the peat was not there, then how much additional storage would be needed?

8.3 Cultural

Cultural ecosystem services are the ones which provide non-material benefits like enjoyment of the landscape, recreation on peatlands and cultural heritage (Bonn et al., 2009). It is difficult to quantify cultural services provided by peatlands because of their subjectivity and how different sectors of society perceive them (Suckall, Fraser & Quinn, 2009).

8.3.1 Archaeology

Peatlands are of considerable historical importance as they can preserve records of interactions between people and places, species, environment, climate and land use over time, for 10,000 years or more. Such records provide insights into past environment and culture, including historic climate changes and land management regimes (Climate Change Committee, 2013). Peatlands have revealed some of the UK’s iconic finds. Examples being Lindow Man ‘bog body’ in Cheshire, the Mesolithic headdress of Star Carr and the Llyn Cerrig

Bach hoard containing over 150 Iron Age objects. There are an estimated 22,500 archaeological sites that may survive within or beneath the peat deposits. As important as large finds are the small microfossils e.g. pollen grains (evidence of past vegetation change), insect and plant remains, as they preserve a record of environmental change over time. A vertical section taken from undisturbed peatland will show changes over time as the peat steadily accumulates. In addition, the character of a landscape may be of value as they show historic land use, such as mining, peat cutting or royal hunting grounds (Payne & Jessop, 2018; Gearey et al., 2010).

Peatlands are exceptional for preservation of organic and inorganic archeological remains due the characteristic waterlogged, acidic and anaerobic (absence of oxygen) conditions of the peat. An archeologist typically finds up to 90% of materials from past communities in peatlands, whereas on dry land up to 10% may be found (Gearey et al., 2010).

Research by Gearey et al. (2010) produced estimates on archeological sites on peatlands based on past surveys and studies. Estimated a total of approximately 22,500 with Scotland having 11,000, England 7,000, Northern Ireland 3,500 and Wales 300. However, there is currently no definitive data on the number of sites in the UK. As of May 2019 Historic England have registered 379 sites linked to peat. This includes Bronze Age and Iron Age trackways, Prehistoric field systems, barrows and buildings with links to industrial and household uses of peat.

The benefits of many archaeological finds in peat come at the cost of the peat itself. Trackways and other finds like bog bodies only become visible when peatland is eroding or damaged. They then get exposed to oxygen and decay. Whereas the well protected sites for archeological remains and paleoenvironmental sequences in healthy peat environments are undiscovered. In the absence of a robust estimate of the number of archaeological sites and their location in peatlands it makes it difficult to provide an accurate estimate of this ecosystem service.

Fluck & Holyoak (2017) identified the historic environment is not well represented in ecosystem services and natural capital accounting. By understanding the historic character of a landscape, it can help to identify the supporting services that makes places special for wildlife and people.

8.3.2 Education and research

Peatlands are widely used as outdoor classrooms providing topics which range from their history and archaeology, through to present day interests and uses their role in influencing, and being affected by, future change.

Numerous National Parks now employ educational officers to accompany educational visits to blanket bogs, written resources for schools and provide information for the public. In addition, conservation organisations have also produced education packs for teachers to use in the curriculum (Bonn et al., 2009). One of the resources created for schools is from Scottish Natural Heritage ‘Peatlands: A guide to educational activities for schools’ (SNH, 2014). An example of education activities is in the Flow Country, a remote area in the north of Scotland, where they have a small laboratory and a field centre with accommodation for research and have learning opportunities through a schools programme (Flows for the future, 2019).

There is no data on the total number of educational visits to peatlands in the UK. Data is available on the publicly funded research on peatlands, with the majority being undertaken at universities. Data in Table 8.10 is from the Gateway to Research website which has a database on publicly funded research in the UK (UK Research and Innovation, 2019). This table shows funding grants for research on UK Peatlands from 2006 to 2019, with research funding having a peak in 2009 with £979,735 worth of funding.

Table 8.10 Publicly funded research grants on Peatlands in the UK

Year	£
2006	88,609
2007	492,934
2008	802,286
2009	979,735
2010	849,978
2011	556,605
2012	582,005
2013	496,657
2014	236,782
2015	453,680
2016	557,489
2017	713,422
2018	882,796
2019	622,027

Source: Gateway to Research

8.3.3 Recreation

Recreation on peatlands is a valuable ecosystem service in the UK, however, it remains poorly quantified. It can be difficult to analyse for peatlands as visitors may not be aware they are visiting a peatland environment. It is easier to identify visits to lowland sites as they are often nature reserves, such as Wicken Fen (Smyth et al., 2015).

Estimates for peatlands are based on apportioning the Monitor of the Engagement with the Natural Environment survey (MENE) from Natural England then upscaled for the whole of the UK (see methodology section for full details). It is estimated time spent in peatlands in 2016 was 179.9 million hours with an expenditure of £273.6 million (Table 8.11).

Table 8.11 Estimated recreational visits, hours spent and expenditure on UK peatlands

	2009	2010	2011	2012	2013	2014	2015	2016	2017
Visits (million)	79.4	76.2	87.6	74.9	96.6	87.2	100.7	104.9	78.0
Time spent at habitat (hours)	115.6	91.7	111.9	122.2	155.8	92.9	119.6	179.9	120.6
Expenditure (£ million)	244.3	216.3	191.8	193.9	284.4	136.7	124.1	273.6	169.0

Source: ONS

Peatlands have been used for recreational hunting over a long period of time. During the late 19th and early 20th century hunting changed from walked-up shoots with gun dogs to driven grouse shoots (Natural England, 2010). PACEC (2014) estimated in the UK 700,000 red grouse were shot and 74,000 red deer stalked in 2012/13. It was also estimated a total of 1,700,000 shooting days in the UK in 2012/13, with an estimated spend of £2.5 billion on the goods and services. The majority of the spending was on shoot subscriptions and shooting fees. However, this is for all hunting habitats and peatlands cannot be identified in these figures. Further details on recreational shooting can be found in the MMH Natural Capital publication (ONS, 2019). The Scottish Government commissioned research investigating the costs and benefits of large shooting estates to Scotland's economy and biodiversity. The review found there is an estimated £23 million of Gross Value Added to the Scottish economy from grouse shooting and related activities in 2009 (Brooker at al., 2018).

Currently there is no data available for recreational hunting just on peatlands and it will be excluded from ecosystem services for peatlands. Further research is needed to provide time spent and the values of the benefits from peatlands.

8.3.4 Sense of place/aesthetics/image

An important but less tangible benefit provided by peatlands is their important role in shaping the 'sense of place' in the landscape. In Scotland the peatlands provide iconic backdrops which are valued by tourism and film industries and play an important role in the brand for food and drinks.

In England peatlands generally form a significant part of its natural heritage with large tracts of semi-natural habitat. These areas provide a sense of 'wilderness', a now rare habitat within the typical heavily modified landscape. Many areas of uplands with blanket bog are designated as Areas of Outstanding Natural Beauty (ANOBs). They also get referred to as "landscape designations" as they provide conservation and enhancement of biodiversity, and help link people with nature (Natural England, 2012).

Peatlands are an area of cultural enrichment and have provided inspiration for literature, such as the Hound of the Baskervilles and Lorna Doone, and in art, song and poetry over time. Even today their evocative colours are captured in some tweeds and tartans in Scotland.

The European Landscape Convention (ELC 2000) protects and manages landscapes in Europe and which the UK signed in 2006. This convention recognises the relationship between people and place and it states the landscape "contributes to the formation of local cultures and … is a basic component of the European natural and cultural heritage, contributing to human well-being and consolidation of the European identity". Giving prominence to the landscape being more than a view and it is important how people interact with the landscape and their experiences gained from their interactions (Bonn et al., 2009).

9. Future development

Smyth et al. (2015) identified a comprehensive list to developing future peatlands accounts. The major advancement since 2015 has been the completion of a unified peatlands map for the UK and estimate of the different land use categories for peatlands. To take this further, access is needed to the digital map created for the 'implementation of an Emissions Inventory for UK Peatlands' report (Evans et al., 2017). This report was compiled from multiple sources and subject to different licencing restrictions and is not currently available to access digitally.

This project map made significant advances in mapping the peatlands in the UK and provides the first harmonised peat map of the UK. However, this work highlighted many discrepancies between different maps and defining the boundaries between peat and other soil types. It is recommended to continue to develop the UK peat map and the use of standardised mapping across the four UK administrations.

Further developments are needed to produce repeatable condition mapping of UK peatlands. The condition of the peatlands is continually changing. It is important to know the current condition as peatlands in a good condition provide better ecosystem services.

New data sources for the UK are needed to identify the currently poorly understood contribution timber, wind power, flood hazard regulation, water quality, carbon storage and recreation bestow to peatlands ecosystem services.

10. Restoration

10.1 Introduction – Objective & Approach

In this section we estimate the cost of restoring the UK's peatlands. A restoration cost account requires a clearly defined objective. The ONS Peatland account is "cross cutting" because peaty soils are found across the UK's nations and in a variety of habitats and circumstances. There are a variety of government and legal objectives for some peatlands but there is no single objective with a detailed course of action (for example see Natural England, 2010). The Committee on Climate Change suggest 55% of peatlands should be restored by 2050 in Committee on Climate Change (2019) and suggest that this would not include all lowland agriculture but do not provide detail on which 55%.

In addition, we can only gather a relatively coarse description of the condition and extent of peatlands. This presents a challenge to a policy neutral organisation since we must make appropriate assumptions.

Objective

This section therefore begins with the simplest possible assumptions and chooses the coarse objective of restoring peatlands to near natural condition. Between the current state of peatlands and "near natural condition" there are a range of compromise solutions which decision makers may find preferable. A coarse objective has the benefit of enabling us to simply estimate the cost of stopping some activities and starting others. An approach which yields simpler calculations and stark outcomes which better illustrate the potential trade-offs than approximations of potential compromises. There are also new activities which might be used but their novelty means that there are few good economic data making a useful analysis even harder.

The most notable implication of our approach has been for us to assume that all crop farming would cease on peatlands. The Office for National Statistics is a not a policy making agency and in no way advocates any particular policy. By initially making the assumption that all farming would cease the intention is not to suggest that this will or should occur – it is done because it is possible to cost this option and it would achieve the stated objective for those landcover types. Alternative ways to maintain agriculture on these lands and reduce carbon emissions are being explored.

Evans et al. (2016) examine the impact of raising the water table on emissions on agricultural lands and find that raising the water table 10 cm can save 4 $MTCO_2e$/year. The Committee on Climate Change (2019) suggests that seasonal management of the water table in agricultural lands could save 1.5 $MtCO_2e$ in 2050. We understand that further work is needed before we fully understand how water table management trades off with agricultural output.

This section presents our current best estimate of the cost of restoring each type of peatland to near natural condition and the net impact of restoring all peatlands to illustrate the issue. We then present alternative methods for prioritisation of the restoration of 55% of all peatlands with and without croplands because of the specific uncertainty surrounding it.

Baseline

The baseline for this work is the current state of the world. As such there are a number of costs which might be incurred under the counterfactual which are not included in the valuation. For instance, if water pumping is required now and if we restore peatlands that cost is not included. The cost may move from private to public hands (or vice versa) but the net impact on the UK will be the same as these are transfer costs not highlighted in this form of analysis.

Approach

The account is built from the basic landcover types defined in the 'Implementation of an Emissions Inventory for UK Peatlands' report by CEH (Evans et al., 2017) matched against a set range of land management activities. We first considered which of the land management activities would be required for each peatland type to convert it to a near natural state. This work was desk based and checked with our steering group and other experts.

A per hectare cost for each intervention was estimated. Where the cost would be over a number of years the future costs were discounted using the Green Book discount rate to estimate the current value of that intervention per hectare for the period of time over which it is expected to be incurred or 100 years for perpetuity.

If a given landcover type is identified as requiring a given intervention the present value of the cost is multiplied by the total area of that landcover type. Then the total cost of all interventions on that landcover type are added together before the cost of all landcover types are added for a UK cost.

10.2 Land Cover

*Table 1*0.1 describes the landcover types found across the UK's peatlands as calculated for CEH (Evans et al., 2017) plus assumptions made in section 8.1.3 of this report regarding cropland. There are currently just under 640,000 ha of near natural bog and a little under 3,000 ha of near natural fen. Near natural habitats make up only 22% of the nearly 3 million hectares of peatland in the UK.

The remaining land is assumed to be under some form of economic management. We assume in section 8.1.3 that 1.7 million hectares of peatland are farmed with 133,000 ha under horticulture, 61,000 ha under arable, and livestock farming on just under 1.5 million ha. The remainder is either forestry or extraction for domestic fuel or sale.

Table 10.1: Peatland Landcover types and area for the UK

Land Cover	**Area (ha)**
Forest	439,292
Cropland_horticulture	133,000
Cropland_arable	61,125
Drained Eroded Modified Bog	82,989
Undrained Eroded Modified Bog	245,360
Drained Heather Dominated Modified Bog	182,659
Undrained Heather Dominated Modified Bog	513,314
Drained Grass Dominated Modified Bog	65,438
Undrained Grass Dominated Modified Bog	166,916
Extensive grassland	42,682
Intensive grassland	190,147
Near Natural Bog	636,238
Near Natural Fen	2,674
Extracted Domestic (fuel peat)	136,853
Extracted Industrial (horticultural)	8,034
Rewetted Bog	29,102
Rewetted Fen	24,871
Total	**2,960,694**

10.3 Actions

Conceptually the restoration of peatlands can be broken down into 4 basic objectives:

1. Stop or mitigate the activities damaging the peat.
2. Remove unwanted vegetation
3. Ensure the ground remains sufficiently wet
4. Add the required plant species if they are absent

The first objective is measured as the opportunity cost since we would assume the current activity is profitable. Objective 2: Removing vegetation could mean deforestation or mowing grass and the costs involved vary dramatically between sites depending upon accessibility and the machinery available.

Objective 3 is perhaps the most varied challenge. Much of the work goes in to "re-wetting" the land – though in some fenland areas it may be necessary to also pump water out. Peatlands naturally hold on to water and to enable economic activity on these lands drains were cut to allow water to run off.

Various means are used to block drains. Grip blocking can be as simple as moving peat into the drains or involve bringing in stone or wood to create damns where drains are larger. In the worst cases water runoff has dug deep steep trenches or peat hags. Where there are particularly large and steep drains machinery can be brought in to reprofile the land and flatten it out.

In the fens there are areas where the peatlands are below sea level and a system of pumps are used to maintain water levels (fens for the future (accessed July 2019)). For our purposes this can be considered the baseline. Since that pumping would still be required if the land was restored to near natural condition we could arguably assume no change in cost and leave this out of the calculations.

Wetlands are climax habitats meaning that they should not develop into other forms of habitat if they are properly restored. However – there may be some areas where long term management is necessary. For instance, mowing of reedbeds in fenland is likely to be needed long term to prevent them from drying out.

Objective 4 involves seeding areas with sphagnum moss where necessary. Sphagnum mosses are the driving engineers of the peatlands and vital to restoration.

For a summary on peatland management we would recommend IUCN (2016).

Stop/Mitigate Damaging Activity

We have already mentioned mitigation of damaging activity since it is the trickiest area to deal with. There is a very simple way to achieve this objective which is to stop all farming, forestry and peat extraction on peatlands. However, for other reasons this may not be desirable for stakeholders and decision makers.

However, it would be very difficult to estimate the economic impact of some of the other possible activities in this area. There are fewer data on the economics of, “compromise” solutions. In order to make this work tractable we begin with the basic assumption that all economic activity ends before relaxing that assumption where that is compatible with the objective of restoration to near nature condition.

Opportunity Cost

We take the cost per hectare from section 8.1.3 of the main report. Copied in table 10.2 are average whole farm costs for pertinent farm types. The most pertinent caveats to this use of data would be that there is no breakdown in the Farm Business survey by soil type and that we are currently relying on England only data. For instance, the average income for all horticultural farms may be larger or smaller than the average income for horticultural farms on peatland. With respect to the national differences this will affect the accuracy of our data. However, following discussions with economists with more experience of the FBS it was decided that given the approximate nature of this work the use of national breakdowns would be unlikely to significantly shift the scale of values.

Table 10.2 Agricultural income by farm type

Farm Type	£/ha/year	Present value £/ha
Horticulture	556	16,613
Cropland	-13	-383
Livestock	-79	-2370
Upland Livestock	-89	-2661

Source: Farm Business Survey + ONS calculations

The yearly values from section 8.1.3 were converted into present value estimates by discounting (HM Treasury, 2019) the stream of values over 100 years.

Landcover Mapping

We used the same assumptions as in section 8.1.3 to map these farm types to peatland types copied in table 10.3.

Table 10.3 Mapping CEH Peatland classifications to Farm Types

Farm Type	CEH classification
Horticulture	Cropland
Cropland	Cropland

sheep	Modified Bog
sheep/grouse	Heather modified bog
Grazing livestock/hay	Grassland

Peatland extraction was estimated separately following a personal communication (Mulholland 2019). Total revenue was estimated for the industry for each year between 2010 and 2015 by multiplying the prices by the production estimates from BGS minerals yearbook (BGS, 2017). The average for these years was £47 million. Mulholland (2019) estimates that the producers receive 12% of that value net of costs giving an industry income of £5.5 million/year (around £695/ha) and a present value of £166 million which is the total opportunity cost of ending commercial extraction now. In the basic value to do not value to domestic extraction.

Alternative Opportunity Cost

The Farm Business Survey data suggests that livestock farms as a whole are making a loss. The ending of livestock farming on peatlands therefore does not provide a, “conservative” estimate of cost. Semi-natural peatlands will remain in good status with some conservation grazing in place (IUCN, 2014c); and so some livestock farming could continue on near nature peatlands. For an alternative opportunity cost of livestock on peatlands we assume current costs remain in place and an additional opportunity cost is incurred for reducing stocking rates to conservation levels. We considered the alternatives for croplands to be too uncertain for a reasonable alternative to be chosen.

Since the alternative livestock value is a marginal change (as opposed to whole farm loss) we use NIX Farm Management book gross margins for livestock per hectare (Redman, 2018). Per hectare livestock figures are multiplied by stocking densities taken from Natural England (2014) per hectare forage costs from Nix are netted off to produce an overall estimate of value.

Baseline stocking (current) rates were chosen from Natural England (2014) to match the CEH based peatland types. Table 10.4 shows the rules by which we matched Base systems to CEH peatland mapping. The counterfactual stocking in all cases was taken from the, “Wetland Grazing System”. The difference between the marginal income of the base system and the counterfactual gives the opportunity cost incurred per hectare displayed in Table 10.4. Those values were discounted over 100 years to estimate the present value of the counterfactual.

Table 10.4 Alternative opportunity cost estimates for livestock

Base System	CEH Map rule	Baseline (£)	Counterfactual (£)	Net Change (£)	PV Opportunity Cost (£)
Wetland Grazing Base	All Undrained	26.35	15.08	-11.27	-337
Permanent grassland with very low inputs (outside SDA) -Base	Intensive Grass	387.37		-372.29	-11,118
Permanent Grassland with very low inputs (in SDA) – Base	Other	158.30		-143.22	-4,277

The alternative to removing cropland is best represented in the results where we exclude cropland from work to leave 55% of peatland in a near natural state.

Remove Unwanted Vegetation

Deforest

Forest removal can in some cases lead to valuable income. However – as noted in section 8.1.4 the quality of the timber and the difficulty of access can mean that there is a significant net cost to deforestation on peatlands.

In section 8.1.4 it is explained that (Okumah et al., 2019) only have one datapoint for commercial forest removal at a significant net cost. Given the uncertainty that would surround such a figure we rely instead on the deforestation to waste figures. Felling to waste ranged from £437/ha to £3,548/ha with a mean of £1,993/ha. We use the average figure as an appropriate estimate and apply this to all forested peatlands identified by CEH (Evans et al., 2017).

Though the seed bed might lead to reforestation in the early years of development we treat those young trees as scrub removal (next section). This value is therefore included as a single one off cost incurred in the first year.

Scrub Removal

Scrub removal costs were taken from the (Okumah et al., 2019) brush cutting figures which ranged from £125 to £1664/ha. The mean value of £894 was used in the main calculation. Scrub removal was applied to heather dominated bog.

Long term

Scrub removal might be necessary over the medium term. We assumed that removal on a three- yearly basis for 15 years would be sufficient. On forestry the first year was ignored since this was costed as forest removal. From year year 3 to year 15 scrub removal was applied on a 3 yearly basis to remove any regrowth.

Mowing

Reed, sedge and grass growth can dry out fenlands if left unchecked. This mowing may be necessary over the long term (McBride et al., 2011). Mowing costs were taken from (Mills et al., 2015) including removal of the vegetation of £428/ha. The whole area would not be mowed every year. McBride et al. (2011) state that The Broads Authority mows 250 ha of fenland per year. The Broads authority estimates that it has 3193 ha of fenland meaning that 8% are cut per year (Broads Authority, 2009).

We therefore estimate per hectare costs of £33.50/ha which discounts to a present value of £1,001. This cost was applied to all fenlands and we assumed that croplands would be converted to fenland and also require mowing.

Control water Levels

Re-wetting the land is a significant focus of peatland restoration. We briefly touch on pumping but consider this to be part of both the baseline and counterfactual.

Grip Blocking

Moorland gripping is the digging of ditches to drain land. Grip blocking is therefore the reversal of that process. This can be done by simply moving peat for smaller grips (IUCN, 2016) or with rock damns with wider grips. This leads to significantly varied costs. Okumah et al. (2019) estimates the costliest grip blocking to be stone at £5,883/ha and with plastic it can be as cheap as £74/ha. Peat grip blocks range from £103 to £447. We have little data on the rates at which different grip blocking option are used. However, the stone grip blocking costs were based on a single datapoint and so we considered these rare and used the highest of the plastic and peat-based costs of £886/ha (plastic). We assume that grip blocking is required on:

- Drained bogs
- Grassland
- Peat extraction sites

We assume croplands are drained with other infrastructure including pumps.

Reprofile

Reprofiling is needed where erosion has created deep gullies in the peat. It involves physically reshaping the area around the gully to remove it. Okumah et al. (2019) estimate reprofiling at £951/ha to £1,143/ha with an average of £1,031. We assume reprofiling is needed on eroded sites and extraction sites.

Pump

Fenlands are often under sea level and pumped to keep the land clear. To prevent these areas turning into lakes the pumping would need to continue. We made some efforts to find costs to illustrate this but would not have included them in the full accounts. This is because pumping is necessary now and would be if the land were restored to near natural status. Therefore, there is no net change in costs.

Seed

Re-seeding is only necessary where there is no current sphagnum. We applied this cost to: forest, cropland, grassland and extractive sites. Okumah et al. (2019) estimate seeding at £473/ha to £1,213/ha with a mean of £845/ha.

Monitoring

Monitoring costs were taken from Moxey & Moran (2014) of £25 per hectare per year and applied to the total area.

10.4 Results

Tables 10.5 and 10.6 present the basic model costs by landcover type. Table 10.6 gives a present value cost of £8.4 billion of restoring all peatlands to near natural condition. Noting that we have assumed that all upfront costs are incurred in the first year this value would fall in reality since future costs would be further discounted.

Land Cover	Deforest (£)	Grip Block (£)	Opportunity Cost (£)	Scrub Removal (£)	Reprofile (£)	Mowing (£)	Seed (£)	Monitoring (£)
Forest	875508956	0	0	1456172293	0	0	371201740	327968415
Horticulture	0	117838000	2209481725	0	0	133198644	112385000	99295683
Arable	0	54156750	-23394510	0	0	61216294	51650625	45634952
Drained Eroded Modified Bog	0	73528254	-220796133	0	85561659	0	70125705	61958267
Undrained Eroded Modified Bog	0	0	-652791806	0	252966160	0	0	183181871
Drained Heather Dominated Modified Bog	0	161835874	-485972850	768778181	0	0	0	136370302
Undrained Heather Dominated Modified Bog	0	0	-1365696010	2160444343	0	0	0	383232062
Drained Grass Dominated Modified Bog	0	57978068	-174100873	0	0	0	0	48854969
Undrained Grass Dominated Modified Bog	0	0	-444087859	0	0	0	0	124616829
Extensive grassland	0	37816252	-113557466	0	0	0	36066290	31865702
Intensive grassland	0	168470242	-450741946	0	0	0	160674215	141960724
Near Natural Bog	0	0	0	0	0	0	0	475005164
Near Natural Fen	0	0	0	0	0	2677994	0	1996366
Extracted Domestic (fuel peat)	0	121251758	0	0	141095443	0	115640785	102172272
Extracted Industrial (horticultural)	0	7118124	166912310	0	8283054	0	6788730	5998057
Rewetted Bog	0	0	0	0	0	0	0	21727090
Rewetted Fen	0	0	0	0	0	24908146	0	18568293
Total	**875,508,956**	**799,993,322**	***1,554,745,418***	**4,385,394,818**	**487,906,316**	**222,001,078**	**924,533,090**	**2,210,407,018**

Table 10.5 Present value of costs by activity and landcover type

Table 10.6 Total present value of costs by land cover type

Land Cover	**TOTAL (£)**
Forest	3030851405
Cropland_horticulture	2672199052
Cropland_arable	189264111
Drained Eroded Modified Bog	70377752
Undrained Eroded Modified Bog	-216643775
Drained Heather Dominated Modified Bog	581011507
Undrained Heather Dominated Modified Bog	1177980396
Drained Grass Dominated Modified Bog	-67267836
Undrained Grass Dominated Modified Bog	-319471030
Extensive grassland	-7809222
Intensive grassland	20363234
Near Natural Bog	475005164
Near Natural Fen	4674360
Extracted Domestic (fuel peat)	480160258
Extracted Industrial (horticultural)	195100275
Rewetted Bog	21727090
Rewetted Fen	43476439
Total	**8,350,999,180**

Sensitivity Analysis

In this section we begin by pushing all of the costs as high as possible to estimate the overall impact for sensitivity analysis. We use the alternative opportunity costs described and applying the commercial peat income/ha to domestic extraction. We also use the high end costs reported for: Grip Blocking, Scrub Removal, Reprofiling, Mowing and Seeding.

Table 10.7 presents these costs broken down by activity and landcover type. Table 10.8 shows that the total cost increases by more than double from £8.4 billion to £22 billion over the next 100 years.

Land Cover	Deforest	Grip Block	Opportunity Cost	Scrub Removal	Reprofile	mowing	Seed	Monitoring
Forest	1558608016	0	0	2,710,369,906	0	0	532,861,196	327,968,415
Cropland_horticulture	0	782,439,000	2,209,481,725	0	0	162,723,017	161,329,000	99,295,683
Cropland_arable	0	359,598,375	-23,394,510	0	0	74,785,296	74,144,625	45,634,952
Drained Eroded Modified Bog	0	488,224,287	11,885,353	0	94,856,427	0	100,665,657	61,958,267
Undrained Eroded Modified Bog	0	0	2,764,408	0	280,446,480	0	0	183,181,871
Drained Heather Dominated Modified Bog	0	1,074,582,897	26,159,691	1,430,924,937	0	0	0	136,370,302
Undrained Heather Dominated Modified Bog	0	0	5,783,378	4,021,229,740	0	0	0	383,232,062
Drained Grass Dominated Modified Bog	0	384,971,754	9,371,769	0	0	0	0	48,854,969
Undrained Grass Dominated Modified Bog	0	0	1,880,600	0	0	0	0	124,616,829
Extensive grassland	0	251,098,206	6,112,745	0	0	0	51,773,266	31,865,702
Intensive grassland	0	1,118,634,801	70,790,135	0	0	0	230,648,311	141,960,724
Near Natural Bog	0	0	0	0	0	0	0	475,005,164
Near Natural Fen	0	0	0	0	0	3,271,589	0	1,996,366
Extracted Domestic (fuel peat)	0	805,106,199	95,207,716	0	156,422,979	0	166,002,689	102,172,272
Extracted Industrial (horticultural)	0	47,264,022	166,912,310	0	9,182,862	0	9,745,242	5,998,057
Rewetted Bog	0	0	438,920	0	0	0	0	21,727,090
Rewetted Fen	0	0	0	0	0	30,429,204	0	18,568,293
Total	**1,558,608,016**	**5,311,919,541**	**2,583,394,240**	**8,162,524,583**	**540,908,748**	**271,209,106**	**1,327,169,986**	**2,210,407,018**

Table 10.7 Sensitivity test of the present value of costs by activity and landcover type

Table 10.8 Sensitivity test of total present value of costs by land cover type.

Land Cover	**Total £**
Forest	5,129,807,534
Cropland_horticulture	3,415,268,425
Cropland_arable	530,768,738
Drained Eroded Modified Bog	757,589,990
Undrained Eroded Modified Bog	466,392,759
Drained Heather Dominated Modified Bog	2,668,037,827
Undrained Heather Dominated Modified Bog	4,410,245,180
Drained Grass Dominated Modified Bog	443,198,492
Undrained Grass Dominated Modified Bog	126,497,429
Extensive grassland	340,849,919
Intensive grassland	1,562,033,971
Near Natural Bog	475,005,164
Near Natural Fen	5,267,955
Extracted Domestic (fuel peat)	1,324,911,854
Extracted Industrial (horticultural)	239,102,493
Rewetted Bog	22,166,010
Rewetted Fen	48,997,497
Total	**21,966,141,237**

Relative to Carbon Benefits

In order to estimate the climate change benefits of this work we need to estimate when the work would be complete and the benefits start accruing. We have no basis on which to make this assessment. As a simplification we assume all land is fully restored within 10 years, that there are no benefits before this date and all of the benefits come subsequent to it. This would be a simplification of concern if the cost benefit analysis were close. However, as you will see the scale of the difference between costs and benefits is so large that to make this assumption.

We take the emissions per year by landcover type from CEH (Evans et al., 2017) and use the BEIS non-traded carbon price (Gov.uk, 2019) discounted to current prices to estimate the present value of 100 years' worth of value. The total benefits of £109 billion (see Table 10.9) are over five times the highest estimate of the costs we have produced.

Table 10.9 Total carbon emissions per year for each peatland type and expected present value of carbon emissions benefits of restoring peatlands within 10 years discounted over 100 years.

Land Cover	**Net tonnes CO2e /year**	**Present Value (100 years (£))**
Forest	4,353,384	20,497,497,042
Cropland_horticulture	5,184,340	24,409,976,388
Cropland_arable	2,382,653	11,218,494,787
Drained Eroded Modified Bog	402,497	1,895,117,551
Undrained Eroded Modified Bog	871,028	4,101,153,264
Drained Heather Dominated Modified Bog	621,041	2,924,111,147
Undrained Heather Dominated Modified Bog	1,067,693	5,027,132,451
Drained Grass Dominated Modified Bog	222,489	1,047,569,434
Undrained Grass Dominated Modified Bog	347,185	1,634,689,177
Extensive grassland	811,812	3,822,338,613
Intensive grassland	5,683,494	26,760,195,163
Near Natural Bog		
Near Natural Fen		
Extracted Domestic (fuel peat)	1,082,507	5,096,883,292
Extracted Industrial (horticultural)	111,191	523,530,275
Rewetted Bog	23,602	111,126,484
Rewetted Fen	158,428	745,944,581
Total	**23,328,074**	**109,815,759,647**

The Climate Change Committee Objective

Though we have only presented climate change benefits (since these are most readily estimated) restoration cost accounts are built for a broad range of natural capital benefits. The key issue for peatlands is the flux in climate change emissions and we therefore consider The Committee on Climate Change objective of restoring 55% of peatlands.

Since there is no clear description of which 55% should be restored we first removed cropland from the objective since we are uncertain as to the most likely intervention for climate change purposes or its costs. We then ranked each landcover type. First by benefit cost ratio and then total carbon emissions per year. Starting at the highest benefit cost ratio or total emissions we began adding landcover types to the list until 55% of peatlands were included. Once adding a landcover type pushed the total beyond 55% then only the necessary proportion of the lowest ranked landcover was included. We then repeated this exercise including cropland which was ranked high enough to be included each time. We used the "Sensitivity" scenario costs for comparison.

On a Benefit:Cost ratio basis we exclude the Drained Eroded Modified Bog, all Heather Dominated Modified Bogs, drained modified grass dominated bogs and peat extraction. Only 2/3 of forest is included. On an emissions basis we reach 55% while leaving out: extensive grassland, commercial peatlands and all modified bogs except 6% of Undrained Heather Dominated Bog. It is worth noting that these were simply two ways to rank landcover types and alternatives such as ranking by emissions per hectare would be equally appropriate and would, for instance, rank restoration of domestic peat extraction more highly. Domestic peat extraction receives significant attention but falls out of these prioritizations due to its small area.

Scenarios in which we included cropland in the set of landcover types prioritsed led to approximately 16-19 MT CO2e/year as opposed to the 12 MT CO2e/year without it (Table 10.10). The two ranking approaches lead to similar emissions reductions but oddly an emissions based ranking led to higher overall net benefits 10.10.

Table 10.10: Net emissions reduction and net benefits of restoring 55% of peatlands to near natural condition choosing the land included in the 55% based on benefit:cost and total emissions excluding cropland

Ranking Option	Net Emissions Reduction MTCO2e/year	Net Present Benefit (£ Billions)
Benefit:Cost	12	45
Emissions	12	51

11. Discussion

In this report we examined ecosystem extent, condition and service accounts and restoration cost accounts for Peatlands. We used the first unified peat map created by CEH (Evans et al., 2017) and their land use categories for peat to assess peatland condition to assess extent and condition. We found that additional work is needed to update the peatlands extent map developed by CEH. Detailed mapping is needed on extent and condition of the Peatlands if the Peatland Account is to be repeated regularly.

The condition of the peatland has a significant impact on carbon and the climate. Without knowing the true extent and depth of peat deposits it is not currently possible to estimate the amount of carbon currently stored. However, CEH estimated the amount of GHG emissions from the current land use of peatlands, in total around 23,100 kt CO_2e yr^{-1} from peatland sources (Evans et al., 2017).

One of the key services provided by peatlands is the supply and quality of drinking water. It is estimated to supply over a quarter of the UK's drinking water. The value of this service is significant and varies according to location. Peatland in a good condition requires less treatment as the removal of peat sediment and dissolved organic carbon represents a large cost for water utilities.

The food provided by peatland varies by location on its impact to ecosystem services. Upland blanket bogs have a low value as it is mainly suitable for light grazing. Lowland fens are highly profitable for horticulture and arable farming; however, this is at a detriment to the peat from erosion and the release of GHG from agricultural activities.

Recreation is of high value on peatlands, but it is currently unclear on the true value that this provides. Further research is needed to understand the true benefit provided by peatlands. New data sources are also needed to understand the true contributions made from peatlands from timber, wind power, flood hazard regulation and water quality.

The rate of change for identifying the land use habitats is slow. Policy changes are faster, and data is increasingly becoming more accessible to update ecosystem service accounts. With the current data gaps, it is recommended for the Peatland accounts to be updated every 3 years.

The cost of restoring all peatlands to near natural condition were conservatively estimated at between £8 and £23 billion over the next 100 years. This was based on some extreme intervention assumptions. The benefits in terms of carbon emissions reductions along were approximately £110 billion meaning that interventions to reduce emissions are highly likely to be beneficial.

The net benefit of achieving the Committee on Climate Change objective of restoring 55% of peatland by 2050 was estimated to have a net benefit of £45- 51 billion over the next 100 years if croplands are excluded.

12. Methodology

Water Supply

Physical data for water abstraction is sourced from the Scottish Government, Department for Environment, Food and Rural Affairs (Defra) for England, Natural Resources Wales and Welsh Water for Wales and the Northern Ireland Drinking Water Inspectorate.

Monetary estimates are based on resource rents calculated for the SIC subdivision class: Water collection, treatment and supply. The definition of this industry subdivision states: "the collection, treatment and distribution of water for domestic and industrial needs. Collection of water from various sources, as well as distribution by various means is included". A limitation of this approach, therefore, is that the calculated resource rent is not purely related to water supply, but also includes the process of treating the water.

The resource rent can be interpreted as the annual return stemming directly from the natural capital asset itself, that is, the surplus value accruing to the extractor or user of a natural capital asset calculated after all costs and normal returns have been considered. The steps involved in calculating the resource rent are given in Table 12.1.

Table 12.1: Derivation of resource rent

	Output
Less	Operating costs
	Intermediate consumption
	Compensation of employees
	Other taxes on production PLUS other subsidies on production
Equals	Gross operating surplus
Less	Specific subsidies on extraction
Plus	Specific taxes on extraction
Equals	Gross operating surplus – resource rent derivation
Less	User costs of produced assets (consumption of fixed capital and return to produced assets)
Equals	Resource rent

Source: Office for National Statistics

To calculate the asset valuation of the water supply the net present value (NPV) approach is recommended by the System of Environmental-Economic Accounts (SEEA) and it is applied to ecosystem services to estimate the asset value. The NPV approach estimates the stream of services that are expected to be generated over the life of the asset. These values are then discounted back to the present accounting period. This provides an estimate of the capital value of the asset relating to that service at a given point in time. There are three main aspects of the NPV method:

- pattern of expected future flows of values
- asset life – time period over which the flows of values are expected to be generated
- choice of discount rate

This data was then apportioned to represent the water supply from peatlands. From available information we calculated 27% of water supply is from peat catchments. This was calculated by looking at the total volume of water for the four countries from a peat source and taking this as a % of UK total water volume. The percentage of water from peat catchments in Scotland was previously estimated by SNH as 13.7% (Artz et al., 2014). For England and Wales the percentage the uplands which are peatlands was calculated and it was assumed that 70% of this provided an estimate of drinking water from peatlands. England was estimated at 32.1% and Wales with less upland peat was much lower at 5.9%. Data for uplands area in England came from Defra and for Wales from NRW. Data was not found and possibly not available for Northern Ireland, so the same percentage was used as Wales since this was the lowest and most conservative figure.

Peat Extraction

The data on peat extraction volumes and sales income is from the British Geological Survey Minerals yearbooks. Data is at 2017 prices, deflators were applied from the ONS Quarterly National Accounts.

Food

The estimate for extent of agriculture on peatlands is derived from the different land uses data contained in the CEH report ‘Implementation of an Emissions Inventory for UK Peatlands’ (Evans et al., 2017). The high value crops area in the fens is estimated in Graves & Morris (2013) as 133,000 ha. Data on farm income by type of farm is from the Farm Business Survey (FBS). The FBS provides data for England on the outputs from agriculture excluding subsidies, costs for agriculture excluding Agri-environment activities and data on the total farmed area. A £/ha is estimated for the different farm types and applied to the different land use classifications used by CEH. The rate calculated is for England and applied to the whole of the UK.

Recreation

The recreation estimates are adapted from the “simple travel cost” method developed by Ricardo-AEA. The methodological report Reviewing cultural services valuation methodology for inclusion in aggregate UK natural capital estimate is available.

The method looks at the expenditure incurred to travel to the natural environment and expenditure incurred during the visit. This expenditure method considers the market goods consumed as part of making the recreational visit (that is, fuel, public transport costs, admission charges and parking fees). This expenditure is currently assumed as a proxy for a marginal price for accessing the site.

The English recreation estimates were produced using the Monitor of Engagement with the Natural Environment survey (MENE). This survey ran between 2009 and 2017. Over 1,000 face-to-face interviews were undertaken each month, each interview was capped at 30 minutes and was undertaken through a weekly consumer omnibus survey. This is then upscaled to represent the whole of the UK.

The methodological approach followed ensures that the resultant sample for each survey is consistently representative of the adult population in terms of sex, age group, working status and socioeconomic status.

To calculate the element of the MENE survey that is peatlands it was apportioned using the broad habitats that make up peatlands, these being forest, farming, MMH and freshwater. To apportion these habitats the land use classifications designated by CEH were taken as a percentage of the LCM2015 classifications to work out % of peatlands.

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